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Cover: Prairie Falcons, *Falco mexicanus*, Edmonton, Alberta, February 1999. Photo by Robert Gehlert. See article by Dick Dekker and Jim Lange pages .

Hunting Methods and Success Rates of Gyrfalcons, *Falco rusticolus*, and Prairie Falcons, *Falco mexicanus*, Preying on Feral Pigeons (Rock Doves), *Columba livia*, in Edmonton, Alberta

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Dekker, Dick, and Jim Lange. 2001. Hunting methods and success rates of Gyrfalcons, *Falco rusticolus*, and Prairie Falcons, *Falco mexicanus*, preying on feral pigeons, (Rock Doves), *Columba livia* in Edmonton, Alberta. Canadian Field-Naturalist 115(3): 395–401.

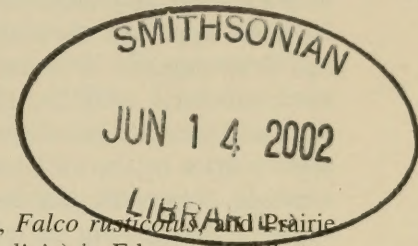
Three adult female Gyrfalcons (*Falco rusticolus*) and one adult female Prairie Falcon (*Falco mexicanus*), wintering in Edmonton, Alberta, killed 15 and 27 feral pigeons (Rock Doves, *Columba livia*) respectively in 141 and 104 hunts. The Prairie Falcon's hunting success rate (26.0%) was significantly greater than that of the Gyrfalcons (10.6%). Six kills (40%) by Gyrfalcons and 18 kills (67%) by the Prairie Falcon were the result of surprise attacks on sitting pigeons. Open attacks on flying pigeons resulted in nine captures each. Gyrfalcons typically attacked airborne flocks of pigeons with upward swoops from below, whereas the Prairie Falcon stooped down at them from above. Both species often resumed hunting immediately or soon after consuming a pigeon. On one occasion, the Prairie Falcon killed four pigeons of which three were abandoned in 20 minutes. Besides capturing live prey, a Gyrfalcon stole a pigeon from the Prairie Falcon, and another Gyrfalcon scavenged four dead pigeons.

Key Words: Gyrfalcon, *Falco rusticolus*, Prairie Falcon, *Falco mexicanus*, hunting methods, feral pigeon, Rock Dove, *Columba livia*, Edmonton, Alberta.

Gyrfalcons (*Falco rusticolus*) take a wide range of avian and mammalian prey including Rock Doves (*Columba livia*) (Palmer 1988; Clum and Cade 1994), but descriptions of their hunting methods are generally based on few field observations and do not include hunting success rates (White and Weeden 1966; Bengtson 1971; Dobler 1989; White and Nelson 1991; Garber et al. 1993). The diet of Prairie Falcons (*Falco mexicanus*) includes pigeons but consists mainly of small mammals and passerines (Anderson and Squires 1997; Steenhof 1998). The literature contains few data on hunting success rates of Prairie Falcons capturing avian prey. Dekker (1982) saw 36 hunts including one kill. Beauvais et al. (1992) recorded 37 hunts with five captures. To the best of our knowledge there is only one published account on the foraging habits of Gyrfalcons wintering in an urban environment (Jenning 1972), and none on Prairie Falcons. This paper presents a relatively large sample of hunting flights and success rates of Gyrfalcons and a Prairie Falcon preying on pigeons in Edmonton, Alberta, over two winters, 1998–2000.

Like all big cities, Edmonton harbours a large, year-round population of feral Rock Doves. They commonly attract falcons. Urban Merlins (*Falco*

columbarius), which prey mainly on small birds (James and Smith 1987), occasionally kill pigeons in Edmonton during winter (Lange 1985, and unpublished notes). Peregrine Falcons (*Falco peregrinus*), which nest on high buildings in Edmonton, hunt pigeons but are absent from mid October to late March (Gordon Court, Alberta Environment). Gyrfalcons breed in arctic regions and some migrate south in winter (Godfrey 1986; Clum and Cade 1994). The earliest arrival date for central Alberta is 25 September, and sight records for the city of Edmonton range between November and March (Dekker 1983; Lange 1995). Prairie Falcons are breeding residents in southern Alberta up to the latitude of Red Deer (Godfrey 1986), and there is one (1978) nesting record from west of Edmonton (Gordon Court, Alberta Environment). Prairie Falcons are transients in north-central Alberta from spring to fall, but they summer in the Rocky Mountains up to the latitude of Jasper National Park, where they have been sighted in all months of the year (Dekker 1982, 1984, and unpublished field notes). This paper includes a first record of the Prairie Falcon wintering in the city of Edmonton.



Study Area, Methods, and Description of Falcons

The study area is centred on the Alberta Grain Loading Terminal (the Granary) that is situated along the railway corridor that transects the city of Edmonton (Figure 1). The 43 m elevator building includes an annex loading-shed. Its flat roof is littered with spilled grain and canola seeds on which feral pigeons feed. Varying numbers, up to an estimated 600, roost on the tanks and chutes above the annex and on the window sills of the main building.

At the approach of a falcon, most pigeons fly up and draw together in dense flocks that either course back and forth over the area or depart. Alerted by such anti-predator behaviour, the second author (JL), who works in the rail yards and lives near the Granary, was each year the first to sight wintering falcons. Beginning in mid-December 1998, we recorded all foraging activity (hunts). We defined a hunt as a completed attempt at capturing prey of which the outcome was known (Dekker 1980). A hunt could include one or more swoops or stoops at a pigeon or a flock of pigeons. If the falcon abandoned or interrupted its efforts by a spell of perching or by flying off, its next attack was considered another hunt. Thus, a hunting sequence could include more than one hunt.

The hunts reported here combine those seen by both authors, alone or together. JL's work often placed him in a position to observe falcon activity

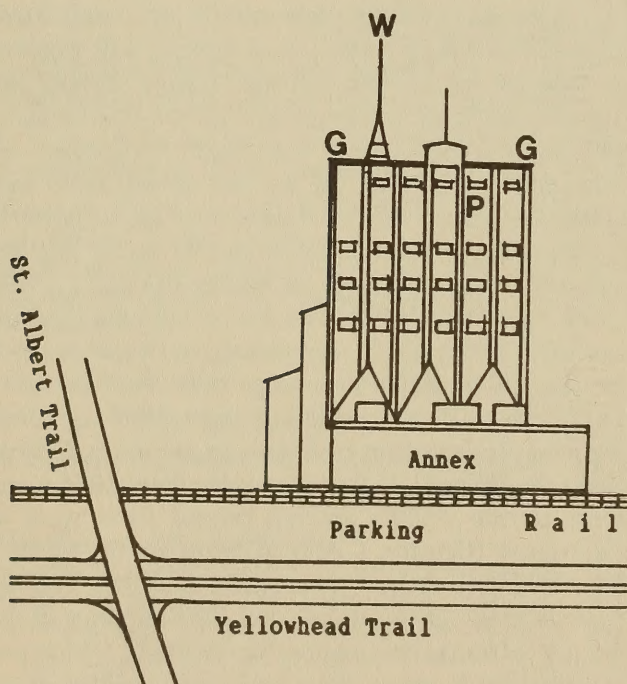


FIGURE 1. Location sketch of the Alberta Grain Terminal near the intersection of Yellowhead Trail and St. Albert Trail in northwest Edmonton, Alberta. The habitual perches of the white Gyrfalcon, the two grey Gyrfalcons, and the Prairie Falcon are indicated, respectively, by the symbols W, G, and P.

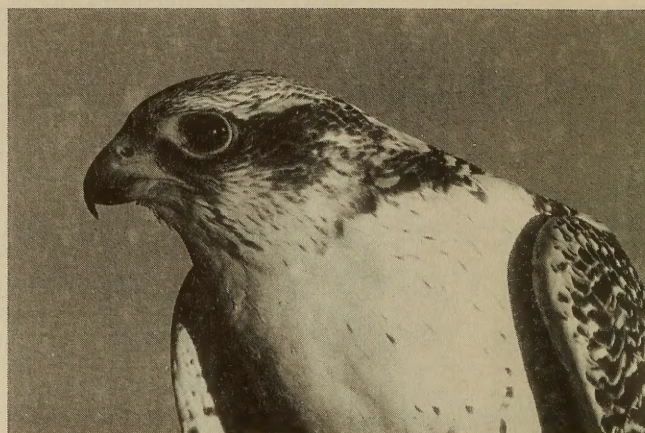


FIGURE 2. This recognizable, mostly white adult female Gyrfalcon, *Falco rusticolus*, roosted on a grain silo in Edmonton, Alberta, over six consecutive winters, 1995–2000. Photograph by Gordon Court.

during the week. In addition, on some days he watched from a parked vehicle just south of the Granary. DD watched from the same parking lot on 37 days in 1998–1999 and on 7 days in 1999–2000, usually from 11:00 to 16:00. Particularly during weekends, one or more associate observers (listed in the acknowledgments) spent varying amounts of time watching for falcons at the Granary. The pigeon kills they reported to us contributed to our understanding of the hunting methods used by these falcons. Weather conditions during observations varied and daytime highs ranged from 5° to –30° C. The ground was covered with 10 to 50 cm of snow.

We saw at least three different adult female Gyrfalcons in the study area. One was mostly white, the others grey variants (Cade et al. 1998). The “white gyr” was lightly spotted on flanks and leg feathers. Dorsally, it was grey-brown with fine barring that gave it a “ladderback” appearance. The crown of its head was light brown unlike other white Gyrfalcons which have white heads (Brown and Amadon 1968). The white gyr was first seen on 15 January 1995 when it was perched on a staircase railing near the top of the Granary (Lange 1995). It roosted in the same spot over the next six winters although it could be absent for several nights in a row. Use of specific roosting sites, with occasional absences of one or several days, was also typical of Gyrfalcons wintering in Washington State (Dobler 1989). The white gyr usually arrived on its roost at dusk and was gone at first light. During the day, it was rarely seen until the winter of 1999–2000. Then, it often used an antenna on the roof of the Granary as a hunting perch (Figure 1). The last date on which the white gyr was seen each year varied from mid-March to 23 March. This is well past the time most adult Gyrfalcons are believed to return to arctic breeding sites (Platt 1976). At Beaverhills Lake, east of Edmonton, the latest Gyrfalcon sight-

ing, possibly of an immature, was 14 April (Dekker 1983).

Initially, we assumed the white gyr to be a male since it looked smaller, more slender and faster on the wing than a heavily streaked, grey-brown Gyrfalcon (gyr #2) which frequented the study area from 6 December 1998 to mid March 1999. Our assumption was proven wrong on 1 March 2000 when Erhard Pletz captured and banded the white gyr. Its measurements (weight 1780 g, wing chord 405 mm) placed it well within the range of female Gyrfalcons (Palmer 1988; Clum and Cade 1994).

Gyr #2 was observed during the winter of 1998–1999, but not in 1999–2000. Then, a different grey-brown Gyrfalcon (gyr #3) was present from 2 December 1999 to mid March 2000. Ventrally, it was less heavily streaked and its feet were a paler yellow than gyr #2. Gyr #3 was identified as an adult by Gordon Court (Alberta Environment). On its left leg, it carried a dull grey (as opposed to a new and shiny) metal band. On 28 November 1998, a similar-looking grey Gyrfalcon, then a first-year immature, was banded by Erhard Pletz on Edmonton’s outskirts. Its weight and wing chord were respectively 1580 g and 400 mm.

We saw no interactions between the white gyr and gyr #2, but often between the white gyr and gyr #3. The white gyr was slightly larger than #3 and chased it off aggressively. In addition to the individual birds described above, we saw two or three other Gyrfalcons in the city (Court 1999), but they were not in view long or often enough to allow for accurate details as to colour, age group, or sex.

The first Edmonton record for the Prairie Falcon was 24 December 1995 (Lange, unpublished notes). Its yellow feet, large size and the dark axillar markings running down much of the wing identified it as an adult female (Wheeler and Clark 1995). In this paper, we refer to it as “the” Prairie Falcon although we have no proof that all sightings involved the same individual. During the winters of 1996–1998, JL and associate observers EJ and JP saw the Prairie Falcon

attack and capture at least eight pigeons at the Granary, but no detailed tally of hunts and kills was kept until the start of this study. During the winter of 1998–1999 the falcon was present from 5 December to 26 February. In 1999–2000, it was first sighted on 2 December but not after the end of December.

Results and Discussion

Gyrfalcon Hunting Methods

Gyrfalcons commonly hunt very low over the ground, and they seize avian prey just after it flushes. The target may be first spotted from an elevated perch (White and Weeden 1966; Bengtson 1971; Palmer 1988; Clum and Cade 1994). A similar strategy of surprise was also employed by the Gyrfalcons in this study. From a perch on the roof of the Granary, the falcons launched attacks on pigeons seeking food or grit along the railway or on snow-free parking lots in the neighbourhood. The hunt could be partially obscured from our view behind buildings so that its outcome could not be determined unless the falcon came back into view, either with or without prey. From their perch on the Granary, falcons launched similar surprise attacks on pigeons sitting on the flat roofs of adjacent, much lower buildings. The above methods resulted in two captures (Table 1). Three similar kills were reported to us by associate observers EJ, BG and JG. In addition, on a day when the number of pigeons at the Granary was small, BG saw gyr #2 drop down from its high perch and seize a pigeon just as it flushed from the roof of the annex.

Surprise was also the initial strategy if the falcon approached the Granary from afar. Flying between adjacent buildings or along the railway, its sudden arrival caused the pigeons to flush in a panic from the annex or the front of the Granary. Typically, the falcon shot upward through the dense flock. In four instances, it seized a pigeon at once. Associate observers DL and JF reported two similar captures. In a variant of these surprise tactics, gyr #3 started its attack from a perch on the side of the Granary.

TABLE 1. Captures of feral pigeons by Gyrfalcons and Prairie Falcons wintering in Edmonton, Alberta.

	Gyrfalcon	Prairie Falcon
Low surprise attack on pigeon(s) sitting on the ground	1	-
Surprise attack on pigeon(s) sitting on flat-roofed buildings	1	-
Vertical swoop from high perch on building at pigeons sitting 25 m lower down	-	10
Sudden attack on flock flushed from building, first pass successful	4	8
Repeated attacks on free-flying flocks, prey seized from flock	8	8
Pursuit of lone pigeon leaving flocks under attack	1	1
Total	15	27
Total number of hunts (successful and unsuccessful)	141	104
Success rate	10.6%	26.0%*

*G-test, G=6.82. P ≤ 0.01 (Sokal and Rohlf 1969)

Flying around the corner of the building, it seized one pigeon from a flock that flushed from the annex below (JF).

If the falcon's first pass failed, it either (1) perched on the roof of the Granary; (2) left the area to hunt elsewhere; (3) went out of sight behind the Granary complex and came back suddenly around the corner to again attack flushing pigeons; or (4) made open attacks on the flying flock. In the latter case, it did so in a deceptively casual manner, flying back and forth near the careening pigeons. After gaining a strategic position in relation to its target, the falcon suddenly descended in a burst of speed with beating wings and, carried by its momentum, swooped upwards into and through the flock. Twisting aside or "standing on its tail," practically stalling at the apex of its swoop, the falcon attempted to seize the nearest pigeon. If it failed to make a capture, it turned back down and might repeat its upward swoops up to six times. Alternately descending and ascending, the falcon typically attacked (as BG termed it) "like a pendulum." We saw eight captures. Associates reported at least another eight, all by the grey falcons.

The white gyr rarely attacked flocks in the above described pendulum-swoops, and instead employed a very different hunting method: direct pursuits of lone pigeons or small groups passing by the Granary, often well over 100 m distant. Starting from its high perch on the antenna, the white gyr quickly overhauled the pigeons, which dodged the attack at the very last moment. The falcon seldom made a second try at the same target. Despite its impressive speed, the white gyr was usually unsuccessful. On 17 February 2000, over a three-hour period, it alternated at least 12 attacks on single pigeons and flocks with spells of perching, yet it failed to make a kill. On 20 February, over two hours, it made about 20 futile hunts. We saw one kill by the white gyr. Here too, surprise may have played a role. Breaking off its attack on a flock, the gyr flew about 50 m in direct pursuit of a single pigeon that had left the flock. Failing to dodge, the pigeon was seized from behind. Gyr #2 never tried to capture single pigeons that flew by while it was perched on the Granary. Gyr #3 rarely did so and always without success.

Prairie Falcon Hunting Methods

Prairie Falcons take a wide variety of prey, including pigeons (Palmer 1988). They often soar to great altitudes and descend in long glides to surprise small mammals and ground-dwelling birds, but during winter they generally hunt low over open terrain (Dekker 1982; Anderson and Squires 1997; Steenhof 1998). The Prairie Falcon observed in this study attacked prey sitting on large city buildings, and surprise was the initial strategy in 67% of its kills. Its most common method was a sudden approach to the Granary. We rarely spotted the falcon before the

pigeons flushed in alarm. Swooping through the flock, the falcon could be immediately successful (Table 1). If it failed, it often took up a perch on the Granary. Unlike the Gyrfalcons which sat on the roof corners or the antenna, the Prairie Falcon always perched on a metal bracket supporting the vertical pipes that ran down the front of the Granary (Figure 1). The falcon's perch was below the roof line but still about 25 m above the annex. After the pigeons had settled back onto the flat roof and machinery below, the falcon suddenly dropped off its perch and stooped down perpendicularly. As the pigeons flared away from the building, the falcon passed through them and might at once emerge carrying its prey. In a similar attack, when few pigeons were present, the stooping falcon passed in between the machinery above the annex, levelled off just over the flat roof and seized a sitting pigeon from behind, carrying it along without pause.

If its surprise tactics failed, the falcon either (1) returned to its bracket perch and tried again 5–25 minutes later; (2) left the area to hunt elsewhere; or (3) pressed its attack on flocks that had already been flushed. This latter hunting method did not involve surprise as the primary strategy. The falcon, either flapping its wings or sailing and soaring, typically stayed close to or above the flock or flocks of pigeons that were careening back and forth. Selecting an individual target on the outside of the flock, the falcon then stooped down with rigid wings, either fully extended or tucked in close to the tail. If the pigeon dodged the attack, the falcon pulled up and directed subsequent stoops at other targets. Some hunts included five or six stoops. A hunting sequence could last five or ten minutes with the falcon sailing away some distance and returning to attack again, perhaps a different flock. Meanwhile, some pigeons might settle back onto the Granary, while others had remained there, crouching on window sills or machinery. The falcon flushed these pigeons by stooping close to the building or passing in between the pipes and tanks above the annex. If it attacked the flushed pigeons, it seldom chased them farther than 10–30 m.

On 4 January 1999, the Prairie Falcon made a series of four kills in about twenty minutes (DD, GC, JF). The first three prey were taken from flocks at the falcon's first pass and carried to a nearby snow-covered parking lot. They were abandoned a few minutes later, probably because of the approach of vehicles. Each time, the falcon flew directly back to the Granary and seized its next prey from the flushing flock. After its third kill, the falcon perched briefly on a pole by the parking lot. It then returned to the Granary and caught a fourth pigeon, carrying it out of sight. By searching the parking lot and following a trail of blood drops, GC and DD located the falcon's three previous kills lying in 30 cm of soft snow.

Food Habits, Scavenging, and Kleptoparasitism

On several occasions, a Gyrfalcon attacked the pigeons at the Granary immediately after it had killed and consumed one. The Prairie Falcon, after we had observed it capture and eat a prey, twice flew to its usual perch with a slightly bulging crop and began attacking the pigeons about 25 min later. On both occasions, it killed and fed upon a second pigeon within two hours from the first. As Rock Doves weigh 250–400 g, the falcons in this study apparently killed well in excess of daily food requirements which are reported to be 250 g for Gyrfalcons and 170 g for Prairie Falcons (Craighead and Craighead 1956; Palmer 1988).

All kills we saw, including those reported by associates, occurred between 10:30 and 16:30. Although we saw no hunting or feeding activity before 10:00, that possibility remains to be investigated more closely. In this regard it may be significant that the white gyr, on the day it was trapped, came down to the lure pigeon at first light. The previous night it had arrived at its roost with a bulging crop as proof that it had eaten well (Erhard Pletz, personal communication).

Both species of falcon carried their freshly-caught pigeons to open terrain such as the parking lot adjacent to the Granary. We did not see them pluck prey on poles or buildings. The Gyrfalcons did not avoid snow of 20–40 cm deep, but the Prairie Falcon usually selected bare ground along the railway. The falcons sometimes carried their prey to the Municipal Airport, about one km away, where the runways were mostly clear of snow.

There appeared to be little overt antagonism between the Gyrfalcons and the Prairie Falcon. Gyr #2 occasionally chased the Prairie Falcon. At other times, both perched on the Granary at the same time. Opportunistic klepto-parasitism might be common but we saw only one such incident. On 13 February 1999, the Prairie Falcon caught a pigeon at the Granary. Gyr #2 was perched on the roof and took off in pursuit. After the loss of its prey, the Prairie Falcon at once returned to the Granary and caught another pigeon out of the flushing flock. We did not see any klepto-parasitism among the Gyrfalcons.

Gyrfalcons are known to feed on carrion in their northern breeding grounds (Dementiew 1960; Palmer 1988; Cade et al. 1998). On 19 February 2000, after eight unsuccessful attacks on flocks of pigeons, gyr #3 landed on the flat roof of the annex, walked to the remains of a dead pigeon, and flew off with it. On 21 February, it retrieved two dead pigeons in about forty minutes. As proof that it had eaten from the first carcass, the gyr showed a bulging crop. On 22 February, it again retrieved a dead pigeon from the annex. Clutching the carcass in its feet, the gyr soared over the area and drifted away.

On 24 February, in preparation for an unsuccessful attempt to trap gyr #3, GC removed eight pigeon carcasses from the annex. Apparently, their death had been accidental, caused by interference with roof fans. However, it is possible that some of the pigeons had died as a result of wounds caused by falcon attack. Once, as gyr #2 swooped upwards through a flock, a pigeon dropped out and fell like a stone in between the machinery above the annex. The falcon made no effort to retrieve it. Other pigeons might have succumbed to injuries sustained during attacks. Some pigeons flapped their wings while being carried off by the falcon. Both the Gyrfalcons and the Prairie Falcon killed some of their prey by biting it during flight. One struggling pigeon freed itself from the gyr's grasp after it had been carried about 100 m. The gyr did not pursue it but returned to the Granary.

In one instance we saw the Prairie Falcon strike a flying pigeon a mortal blow that caused it to stop beating its wings and make a tumble. The falcon instantly doubled back and caught the pigeon before it had fallen more than 3 m (DD and BG). In all other captures the Prairie Falcon directly seized the prey in its feet. Contrary to reports that Gyrfalcons commonly strike prey in the air, so that it drops to the ground (Dementiew 1960; Clum and Cade 1994), the Gyrfalcons in this study seized their prey directly. In close but unsuccessful attacks, the pigeons might lose a puff of feathers, or the falcons trailed feathers from their claws even though all pigeons flew on. Such damage was likely the result of misdirected attempts at seizing prey. Loose feathering in pigeons may be an anti-predator adaptation. Seizing prey, as opposed to striking them down, is also the most common capture method of the Peregrine Falcon (Dekker 1999).

The avian prey of Gyrfalcons consists mainly of grouse and waterfowl (Brown and Amadon 1968; Palmer 1988; Clum and Cade 1994), which are less manoeuvrable in flight than pigeons. Jennings (1972) noted that a Gyrfalcon wintering in Stockholm, Sweden, ignored pigeons. Bent (1937–1961: 2) cited three eyewitness accounts to the effect that Gyrfalcons often tried but “never succeeded in capturing a pigeon.... which were more than a match for them.” This contention is supported by some of our observations, such as the futility of the white gyr's attacks on single flying pigeons. However, the overall success of the Edmonton Gyrfalcons was 10.9%, which is close to the mean (12.7%) success rate of 13 studies of wintering and migrating Peregrine Falcons (Roalkvam 1985). The fair rate of hunting success demonstrated by the gyrs in this study was related to the effective use of surprise and to their persistence in attacks on flying flocks. The “pendulum-style” swoops reported in this paper have not been described before.

In its swoops on flocking pigeons, the Prairie Falcon seemed capable of capturing its prey at will. Flocking by pigeons and other birds is an anti-predator strategy. However, in our study it was apparent that the pigeons' habit of flocking together, instead of fleeing, rendered them particularly vulnerable, both to the Gyrfalcons and the Prairie Falcon. Hunting success rates reported for the Peregrine Falcon, for which there is a great amount of data from around the world, tend to show a wide range (Cade 1982; Roalkvam 1985) unless sample sizes are large and criteria consistent (Dekker 1999). Comparisons of hunting success rates, even within one species, let alone between different species of falcon, mean little unless they hunt the same kind of prey, at the same locality, and during the same season. In this study, the success rate of the Prairie Falcon in capturing pigeons was significantly greater (Table 1) than that of the Gyrfalcons. This fits the theory that a falcon pursuing prey in the air should have a body mass close to that of the prey in order to match as closely as possible the speed and manoeuvrability of the prey (Andersson and Norberg 1981; Cade 1982).

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Numerous birdwatchers and biologists took advantage of the opportunity to watch Gyrfalcons and Prairie Falcons at the Granary. The following contributed information about the pigeon kills they observed: John Acorn (JA), Gordon Court (GC), John Folinsbee (JF), Bob Gehlert (BG), John Groves (JG), Edgar Jones (EJ), Dennis Lavalley (DL), Jack Park (JP), Lisa Takats (LT), and Fred Wiley (FW). Tom J. Cade and Gordon Court reviewed the manuscript and made helpful suggestions. Gordon Court did the statistical test. Erhard Pletz contributed weights and measurements of trapped Gyrfalcons. Wayne Nelson provided relevant literature. We thank Francis Cook, Anthony Erskine, Stuart Houston, and one other, anonymous, reviewer for their comments.

Addenda

During the very mild winter of 2000–2001, the white Gyrfalcon failed to return to the Edmonton Granary, and sightings of grey gyrs were rare in the city. A Prairie Falcon, seen at the Granary on 13 March by DD, proved to be a different individual, based on plumage characteristics, than the bird seen in 1998–2000. Yet, it used exactly the same perch on the Granary and attacked the pigeons in similar style. It appeared to be less accomplished, however, as all of its 18 hunts, made over a three-hour period, were unsuccessful.

During the winter of 2001–2002, a Prairie Falcon was again frequently seen attacking pigeons at the granary, but Gyrfalcon sightings were uncommon (JL).

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Biodiversity of Adult Damselflies (Zygoptera) at Eastern Ontario Gravel Pit Ponds

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Catling, P. M., and V. R. Brownell. 2001. Biodiversity of adult damselflies (Zygoptera) at eastern Ontario gravel pit ponds. *Canadian Field-Naturalist* 115(3): 402–405.

Adults of twenty-five species of damselflies were recorded at 41 gravel pit ponds in eastern Ontario. Twenty-four of the species recorded are believed to breed in the ponds where they were captured. Species present at 16 or more of the sites included *Enallagma boreale*, *E. civile*, *E. cyathigerum*, *E. ebrium*, *E. hageni*, *Ischnura verticalis*, *Lestes forcipatus*, *L. unguiculatus*, and *Nehalennia irene*. Two provincially and regionally rare species, *Lestes eurinus* and *Enallagma aspersum*, were abundant in some of the pit ponds. With 70% of the eastern Ontario zygopteran fauna, these naturally colonized sites may serve as important habitats for the conservation of biodiversity. The relatively high overall diversity compared to the much lower within-pond diversity is probably related to variation between ponds in flora, fauna, depth and other characteristics. Species specific associations with characteristics of the water body other than chemistry, may make damselflies a valuable group of bioindicators.

Key Words: Biodiversity, bioindicator, ecology, damselfly, Zygoptera, Odonata, *Argia*, *Enallagma*, *Ischnura*, *Lestes*, *Nehalennia*, rare species, Ontario, gravel pit, pond, wetland, habitat, conservation, protection.

Wetlands in parts of southern Ontario have been reduced to 5% of their previous extent, and the decline continues (e.g., Snell 1987, 1989). In some areas ponds created through aggregate extraction may become significant habitats for wetland flora and fauna. For example, 18 species of damselflies were recorded over a three-year period from a single 20-year-old gravel pit in southwestern Quebec (Pilon et al. 1988). It appears that these gravel pit ponds may be valuable in conserving aquatic insect diversity. Unfortunately pit ponds are often filled to avoid liability, or to meet the requirements of Ontario's Aggregate Act, or as part of general restoration processes. An underlying lack of recognition of the value of pit ponds in biodiversity conservation is evident. The present study further explores the value of abandoned pit ponds that have been naturally colonized, as habitats for damselflies. In addition it is intended to contribute to an ecological framework that will enable damselflies to be used more effectively as bioindicators, as well as to provide a basis for ongoing studies of biodiversity of man-made ponds that will involve large sample sizes permitting objective analysis of some of the trends suggested here.

Methods

The number of species and the number of individuals of each species of adult damselfly was recorded at each of 41 eastern Ontario gravel pit ponds (Table 1) during two visitation periods; 15–28 August 1996 and 14–22 June 1997. The ponds ranged from one to 30 acres in size, were 2–80 years old and had a pH range of 7–8. One-half hour to one hour was spent at each site during each visitation period. There had been no purposeful rehabilitation of any of the ponds.

Size, depth, shoreline characteristics and presence of frogs and fish (some of which were introduced) were recorded at each pond to enable tentative correlations with damselfly species occurrences.

As many adult specimens were captured as possible at each site. These were identified and released at the end of the sample period. Some voucher specimens were retained and placed in the national collection at Agriculture Canada (CNC). Specimens were identified using Walker (1953) and Westfall and May (1996) and tabulated for each site. "S-ranks" denoting relative abundance in Ontario were taken from Oldham et al. (2000): S1 = critically imperiled (5 or fewer occurrences), S2 = imperiled (6–20 occurrences), S3 = vulnerable (21–100 occurrences), S4 = apparently secure (more than 100 occurrences) and S5 = secure. Authorities for all scientific names used in the text are found in Table 2.

Results and Discussion

Species and overall biodiversity

Twenty-five species of damselflies were recorded at 41 pit ponds (Table 2). In almost all cases the species recorded are believed to have developed in the ponds where they were captured. Some species, such as *Enallagma aspersum* were recorded infrequently but were very abundant at some of the sites where they were found (Table 2). Other species were not found in large numbers but were still associated with the pond where captured due to their teneral condition or the fact that they were observed in copula (e.g., *Chromagrion conditum*). The low number of *E. vesperum* observed was probably a result of observation during mid-day instead of during the evening when this species is most active. *Amphibia-*

TABLE 1. Names, locations, and numbers of damselfly species recorded for 41 eastern Ontario gravel pit ponds.

Location number	Name	County	Township	Latitude	Longitude	Number of species
1	Central dry	Ottawa-Carleton	Gloucester	45°16'34"	75°34'44"	1
2	shallow pond	Ottawa-Carleton	Gloucester	45°16'57"	75°34'53"	3
3	w shallow pond	Ottawa-Carleton	Gloucester	45°16'50"	75°35'2"	5
4	Twin Ponds	Ottawa-Carleton	Gloucester	45°16'47"	75°34'39"	7
5	Clear Pond	Ottawa-Carleton	Gloucester	45°16'31"	75°35'25"	5
6	Upper Clear	Ottawa-Carleton	Gloucester	45°16'34"	75°35'30"	5
7	Church Dry	Ottawa-Carleton	Gloucester	45°17'3"	75°36'7"	1
8	Johnstons Corner	Ottawa-Carleton	Gloucester	45°17'3"	75°35'48"	8
9	Middle Pit	Ottawa-Carleton	Gloucester	45°16'44"	75°35'43"	7
10	North Dry	Ottawa-Carleton	Gloucester	45°16'44"	75°35'43"	2
11	South Dry	Ottawa-Carleton	Gloucester	45°16'25"	75°34'57"	5
12	South Greely	Ottawa-Carleton	Osgoode	45°16'5"	75°34'2"	6
13	Kemptville	Leeds, Grenville	South Gower	45°0'35"	75°33'57"	14
14	Old Pond	Ottawa-Carleton	Gloucester	45°17'20"	75°35'16"	8
15	Big Dry	Ottawa-Carleton	Gloucester	45°16'47"	75°35'2"	7
16	K-Hwy 43	Leeds, Grenville	South Gower	45°2'32"	75°34'40"	8
17	K-Shrubby Pond	Leeds, Grenville	South Gower	45°1'4"	75°34'34"	8
18	Herbert-Lake	Ottawa-Carleton	Osgoode	45°14'22"	75°34'47"	5
19	Herbert-Pit	Ottawa-Carleton	Osgoode	45°14'12"	75°34'42"	7
20	Herbert-Dry	Ottawa-Carleton	Osgoode	45°14'9"	75°34'10"	10
21	Long Pond Osgood	Ottawa-Carleton	Osgoode	45°9'16"	75°35'11"	7
22	Loughlin Dry	Stormont, Dundas	Mountain	45°3'17"	75°33'59"	5
23	Moore Middle	Leeds, Grenville	South Gower	45°1'8"	75°33'40"	7
24	Moore North	Leeds, Grenville	South Gower	45°1'11"	75°33'44"	9
25	Moore Small	Leeds, Grenville	South Gower	45°7'27"	75°34'47"	3
26	Drew Dry West	Ottawa-Carleton	Osgoode	45°9'7"	75°34'7"	10
27	Drew Dry East	Ottawa-Carleton	Osgoode	45°9'14"	75°34'48"	8
28	Cory Drew Pond	Ottawa-Carleton	Osgoode	45°9'29"	75°34'22"	8
29	Sunset Lake N	Ottawa-Carleton	Osgoode	45°15'59"	75°34'57"	3
30	Greely Bro Pit	Ottawa-Carleton	Osgoode	45°13'53"	75°33'29"	7
31	Big Shallow	Leeds, Grenville	South Gower	45°1'40"	75°34'53"	8
32	West Shallow	Leeds, Grenville	South Gower	45°1'46"	75°34'44"	9
33	East Shallow	Leeds, Grenville	South Gower	45°1'46"	75°34'53"	5
34	Sunset Lake S	Ottawa-Carleton	Osgoode	45°15'56"	75°34'43"	5
35	Bruces Pit	Ottawa-Carleton	Nepean	45°19'31"	75°48'14"	12
36	Burnside Lake	Ottawa-Carleton	Nepean	45°13'9"	75°46'14"	5
37	Costello Pit	Ottawa-Carleton	Nepean	45°14'18"	75°45'11"	5
38	Stanstead Pit	Leeds, Grenville	Nepean	44°47'40"	75°36'11"	3
39	Moore South	Leeds, Grenville	South Gower	45°0'52"	75°33'17"	7
40	North Dump Pond	Leeds, Grenville	South Gower	45°1'40"	75°34'48"	11
41	Quinn Pond	Ottawa-Carleton	Gloucester	45°17'55"	75°37'30"	6

grion saucium, although present in only one pit pond, was well established in marshy springs along the shoreline. *Enallagma exsulans* was found at only one pond but it was a large pond with much ground water flow and shoreline wave action, perhaps simulating the streams where *E. exsulans* characteristically occurs. *Enallagma vernale* is the only species that may not have developed in the pond where it was captured. It is characteristically associated with ponds having a deep, organic bottom unlike its close relative *E. cyathigerum* which is characteristic of pit ponds with sandy bottoms.

The occurrence of twenty-four (not including *E. vernale*) of the 34 species occurring in the local area (Catling and Brownell 1997*; Ménard 1996) [i.e.,

70% of the eastern Ontario damselfly fauna] indicates that pit ponds serve as an important habitat for maintaining damselfly biodiversity. The number of species found at eastern Ontario pit ponds represents more than 50% of the damselfly species present in all of Ontario (47 species of which eight are confined to the Carolinian Zone north of Lake Erie).

The relatively diverse damselfly fauna in pit ponds may be explained in terms of ecological variability at these sites. Although similar in water chemistry, in having few floating and emergent plant

*See Documents Cited section.

TABLE 2. Species recorded in 41 eastern Ontario gravel pit ponds indicating number of ponds recorded in and total number of individuals recorded, and "S" rank.

Scientific Name	Common Name	Number of Ponds	Number of Individuals	SRank
<i>Ischnura verticalis</i> (Say)	Eastern Forktail	37	1163	S5
<i>Lestes unguiculatus</i> Hagen	Lyre-tipped Spreadwing	31	424	S5
<i>Nehalennia irene</i> (Hagen)	Sedge Sprite	23	367	S5
<i>Enallagma civile</i> (Hagen)	Familiar Bluet	21	287	S4
<i>Enallagma ebrium</i> (Hagen)	Marsh Bluet	18	904	S5
<i>Lestes forcipatus</i> Rambur	Sweetflag Spreadwing	16	394	S4S5
<i>Enallagma boreale</i> Sélys	Boreal Bluet	17	384	S5
<i>Enallagma cyathigerum</i> (Charpentier)	Northern Bluet	17	455	S4
<i>Enallagma hageni</i> (Walsh)	Hagen's Bluet	16	356	S5
<i>Lestes congener</i> Hagen	Spotted Spreadwing	12	154	S5
<i>Lestes dryas</i> Kirby	Emerald Spreadwing	11	319	S5
<i>Enallagma carunculatum</i> Morse	Tule Bluet	11	36	S5
<i>Lestes disjunctus</i> Sélys <i>disjunctus</i>	Common Spreadwing	6	54	S5
<i>Enallagma aspersum</i> (Hagen)	Bog Bluet	6	873	S1S2
<i>Argia fumipennis violacea</i> (Hagen)	Violet Dancer	5	25	S5
<i>Coenagrion resolutum</i> Sélys	Taiga Bluet	5	43	S5
<i>Lestes eurinus</i> Say	Amber-winged Spreadwing	4	45	S1S2
<i>Enallagma antennatum</i> (Say)	Rainbow Bluet	3	19	S5
<i>Lestes rectangularis</i> Say	Slender Spreadwing	2	10	S5
<i>Amphiagrion saucium</i> (Burmeister)	Eastern Red Damsel	1	35	S5
<i>Chromagrion conditum</i> (Sélys)	Aurora Damsel	1	4	S5
<i>Enallagma vernale</i> (Gloyd)	Spring Northern Bluet	1	1	S3?
<i>Enallagma exsulans</i> (Hagen)	Stream Bluet	1	2	S5
<i>Enallagma signatum</i> (Hagen)	Orange Bluet	1	2	S4
<i>Enallagma vesperum</i> Calvert	Vesper Bluet	1	3	S4

species, and in lacking quaking mats of vegetation and deep organic sediments, they differ in age, size, shoreline and vegetation structure, depth, permanence, and presence or absence of predators and/or prey including waterfowl, fish, frogs and invertebrates. Different species of damselflies may be adapted to different combinations and/or characteristics of these features. For example, *Argia fumipennis violacea* occurred only in pit ponds with rocky shores; *Lestes unguiculatus* and, to a lesser extent, *Lestes dryas* and *L. forcipatus* occurred around temporary ponds which dried out in late summer; and *Enallagma aspersum* occurred in permanent ponds that were mostly less than 0.5 m deep when sampled. This concept of different pit ponds offering a variety of different niches is supported by the relatively large number of species recorded overall in comparison with the relatively small number at any one site (Table 2).

Diversity within a pond

Considering that many damselfly species can be common in some ponds, but rare in others, it may only be through extensive field study that all of the rare species at a particular site will be recorded. With an average of only 2 hours spent observing at each site in the present study, it is possible that rare species were overlooked. Consequently the individual site diversity is probably under-represented. It is notable

in this context that with more extensive field study of a single gravel pit from spring to fall over a three-year period, Pilon et al. (1988) found 18 species. The number of species recorded from a site in the present study ranged from 1 to 14 (Table 1), with an average of 6.41 and a standard deviation of 2.80. Ponds that were very recently created and entirely temporary had the fewest species. Other factors influencing diversity at a pond appeared to include abundance of frogs and fish as well as pond size.

Characteristic fauna

Ontario damselflies can be split into two major ecological groups; those of streams and rivers (including the genera *Calopteryx*, *Hetaerina*, and most species of *Argia* as well as *Enallagma exsulans*), and those of ponds. The latter group can be subdivided into at least two subgroups; (1) widespread and common species of many kinds of ponds, (2) species of older ponds with deep organic layers and much floating and emergent vegetation. The latter subgroup includes species such as *Enallagma geminatum*, *E. vernale*, *Lestes inaequalis* and *Lestes vigilax*, all of which were conspicuously absent from the present survey, although within range (Catling and Brownell 1997*). The species of pit ponds may be assigned to the former subgroup, and species present at most of the sites may be considered as a characteristic fauna. *Enallagma boreale*, *E. civile*, *E. cyathigerum*, *E. ebrium*, *E. hag-*

eni, *Ischnura verticalis*, *Lestes forcipatus*, *L. unguiculatus*, and *Nehalennia irene* were present at 16 or more of the sites. Some of the rarer species may also be characteristic of certain kinds of pit ponds; e.g., *Enallagma aspersum* may be characteristic of uniformly shallow pit ponds.

Rare species

Until recently *Enallagma aspersum* was considered to be very restricted in Ontario and confined to bog ponds, but it has recently been found in a number of man-made habitats and is now known to be widespread (Catling and Pratt 1997). Although widespread and less restricted by habitat than previously thought, it is still a rare species that is currently known from less than 25 locations. Its abundance in some pit ponds, where hundreds can be seen within a few minutes, make these ponds an important habitat and also provides an opportunity to study the population dynamics of this interesting species.

Another uncommon species previously associated with bogs, *Lestes eurinus*, is also well established in some pit ponds. Although it is more common than previously suspected, it is currently known from less than 20 localities in southern Ontario and is certainly one of the rarest species of *Lestes* in the province. The pit ponds provide an important opportunity to study its ecology.

In eastern Ontario *Argia fumipennis violacea* is a very restricted species. In areas of several townships it occurs only on the rocky shores of gravel pit ponds. Thus the pit ponds contribute to the protection of rare species on both a local and provincial scale.

The presence of rare species as well as high overall biodiversity of damselflies suggest that naturally colonized ponds in abandoned gravel pits are potentially important sites for biodiversity conservation and research. The results provide further support for the general idea (Fox and Cham 1994; Chovanec and Raab 1997) that "artificial wetlands" created according to specific ecological principles can serve as important sites for biodiversity conservation especially with respect to Odonata. Since these ponds have a high collective overall diversity of damselflies, but a low within-pond diversity, they appear to be more variable habitats than their similarities in water chemistry and history would suggest. While certain groups of organisms, such as plants, are useful bioindicators of water chemistry, damselflies may prove to be valuable indicators of other water body characteristics such as permanence, depth, structure, predators and prey.

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String and Net-Patterned Salt Marshes: Rare Landscape Elements of Boreal Canada

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Timoney, Kevin P. 2001. String and net-patterned salt marshes: Rare landscape elements of boreal Canada. *Canadian Field-Naturalist* 115(3): 406–412.

A rare form of wetland, string and net-patterned salt marshes, exist in and near Wood Buffalo National Park in northeastern Alberta and the adjacent Northwest Territories. In two wetlands (Benchmark and Lobstick creeks) examined in August 2001, a benthic blue-green algae/diatom community covered flark bottoms. *Calamagrostis stricta* (Narrow Reed Grass) and *Triglochin maritima* (Seaside Arrow-grass) at Benchmark Creek and *Atriplex subspicata* (Saltbush), *Puccinellia nuttalliana* (Nuttall's Salt-Meadow Grass), and *Triglochin palustris* (Slender Arrow-grass) at Lobstick Creek dominated the strings. *Hordeum jubatum* (Foxtail Barley), *Puccinellia nuttalliana*, *Spergularia marina* (Salt-marsh Sand Spurry), and *Triglochin palustris* were common to both wetlands. Other noteworthy plant occurrences included *Aster ericoides* (Tufted White Prairie Aster), *A. pauciflorus* (Few-flowered Aster), *Carex mackenziei* (Mackenzie's Sedge), *Glaux maritima* (Sea Milkwort), *Monolepis nuttalliana* (Spear-leaved Goosefoot), *Plantago eriopoda* (Saline Plantain), *P. maritima* (Sea-side Plantain), *Scirpus paludosus* (Prairie Bulrush), and *Suaeda calceoliformis* (Western Sea-blite). The wetlands observed were associated with valleys. In order to form, they may require a gentle elevational gradient for lateral flow of saline surface water. The patterns may be related also to soil processes involving excessive soil salts. Soil augering revealed an insufficient amount of peat for the sites to be classified as fens; soils appear to classify as Rego Humic Gleysols. These rare wetlands require study of their mode of formation, distribution, and their biota. I suggest a new type designation: interior patterned saline marsh.

Key Words: meadow, saline, vegetation, wetland, Wood Buffalo National Park, Alberta, Northwest Territories.

String or net-patterned fens are fairly common features of boreal landscapes in Canada (National Wetlands Working Group 1988; Vitt et al. 1996). Patterned fens are composed of open, wet flarks and drier strings. Strings form perpendicular to surface water flow, and are usually sinuous on gently sloping terrain and net-like on more level terrain where surface water flow is multidirectional (Vitt et al. 1996). In such wetlands the strings or nets are the result of peat accumulation.

Inland saline wetlands in Canada are characteristic of the Continental Prairie and Intermountain Prairie Wetland regions, wherever hydrogeological conditions favor their existence (National Wetlands Working Group 1988). Typically inland saline wetlands occupy periodically-flooded flats or terminal basins where alkali salts concentrate by evaporation. The alkali salts (sodium, magnesium, and calcium sulphates and chlorides) may be derived from glacial deposits overlying Cretaceous bedrock; from alluvial and lacustrine soils formed under impeded drainage; from soils subjected to seepage from underlying shales; and from dissolution of soluble Paleozoic evaporite rocks (National Wetlands Working Group 1988; Rawson and Moore 1944; Last 1995). In Wood Buffalo National Park, saline areas may be associated with sodium chloride springs that occur along the dissolution edge of the Cold Lake Formation of marine evaporitic halite (Derry 2001).

Wood Buffalo National Park supports a diverse array of wetlands, ranging from bogs, fens, shrub carrs, meadows, and marshes (Raup 1935; PADPG 1973; Townsend 1973; Cordes 1975; Cordes and Pearce 1979; Dirschl et al. 1974; Timoney 1996), gypsum-karst wetlands of the Whooping Crane (*Grus americana*) nesting area (Novakowski 1966; Kuyt 1981; Timoney et al. 1997; Timoney 1999), and saline marshes/meadows or salt plains (Raup 1935; Airphoto Analysis Associates 1979). The saline communities in the park, such as those at the Salt Plains west of Fort Smith, are typically featureless or are sometimes dotted by mineral-cored upland "islands." Rarely, saline wetlands in the park form string or net patterns reminiscent of patterned fens. In this note I describe some of the biological and physical features of patterned boreal saline wetlands.

Observations

During fixed-wing overflights of the park from 1993 to 1996 I noted string and net-patterned saline wetlands on several occasions (Figure 1). One of these wetlands is accessible by foot from the Salt River hiking trail east of the Pine Lake road, at 59° 48' 40" N, 111° 57' 45" W, in far northern Alberta. I visited this site in August 1994 and again in August 2001. *Calamagrostis stricta*, *Agropyron trachycaulum* (Slender Wheat Grass), *Juncus* (Rush), *Puccinellia*

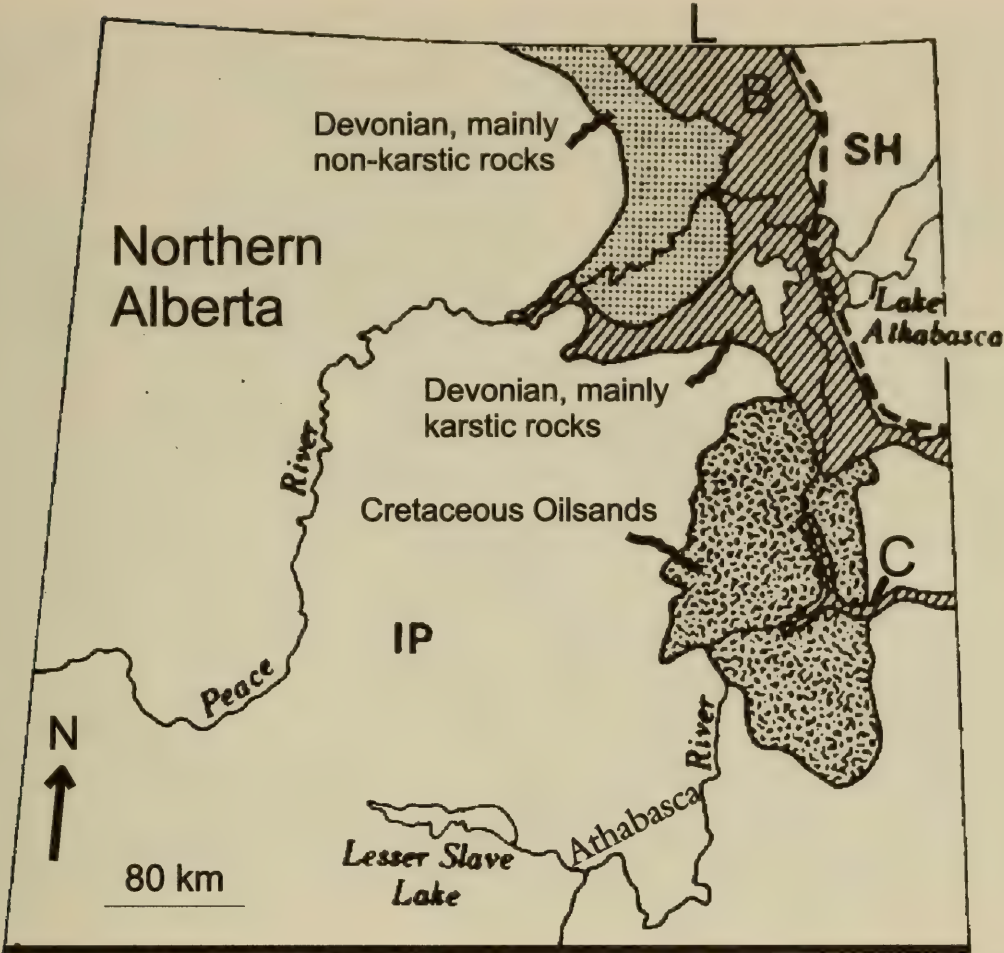


FIGURE 1. Occurrences of patterned saline marshes described in the paper: L = Lobstick Creek, B= Benchmark Creek, and C = Clearwater Springs; all appear to occur in association with Devonian karstic rocks. SH = Precambrian Shield; IP = Interior Plains. Base map after Ozoray (1976).

nuttalliana, and *Hordeum jubatum* meadows, *Salicornia europaea* (Samphire) flats, and semi-barren areas form a mosaic with patterned wetlands in the valley of Benchmark Creek (vascular nomenclature follows Moss 1983; common names follow Alberta Environmental Protection 1993; voucher specimens for difficult or significant species are deposited at the herbarium of the Northern Forestry Centre, Natural Resources Canada, Edmonton, Alberta).

The plant taxa of the strings and flarks on 10 August 2001 (during a wet summer) are listed in Table 1. At the time of sampling, the dominants on the strings were *Calamagrostis stricta* and *Triglochin maritima* and in flarks was a blue-green algae / diatom community with *Triglochin maritima* and *Scirpus paludosus* (Figure 2). A single moss was found: *Amblystegium varium* (Hedw.) Lindb., growing in the shade below the graminoids. Seven years previous (7 August 1994, during a dry summer), the same spot was visited. Strings were then dominated by *Scirpus paludosus* (Prairie Bulrush), along with *Calamagrostis stricta* and *Hordeum jubatum*. *Puccinellia nuttalliana*, *Aster ericoides*, *Atriplex subspicata*, and *Carex mackenziei* were also present. Flarks

(dry at the time of sampling) were barren of vegetation, and were covered by salt encrusted mud and dead roots and rhizomes. No bryophytes were found. Nets in some areas are predominantly mineral, devoid of vegetation or peat. It is possible that at least some of the patterns might arise from a patterned ground process associated with excessive soil salts.

Another fine example of a boreal patterned saline wetland is located in the Northwest Territories, east of the Wood Buffalo park boundary and the Whooping Crane nesting area, in the salt flats near Lobstick Creek (Figure 3; 60° 01' 55" N, 112° 33' 30" W). *Atriplex subspicata*, *Puccinellia nuttalliana*, *Triglochin palustris*, and *Plantago maritima* dominated the strings, while blue-green algae, diatoms, and *Triglochin palustris* dominated the flarks (Table 1). There were no bryophytes found.

The benthic blue-green algae/diatom community covering flark bottoms, and *Hordeum jubatum*, *Puccinellia nuttalliana*, *Spergularia marina*, and *Triglochin palustris* were common to both wetlands.

Lobstick appeared to be rich in bird life, with flocks of Canada Geese (*Branta canadensis*) (feed-



FIGURE 2. Ground level view of flarks and strings at Benchmark Creek valley, 10 August 2001. Photo courtesy Mark Bradley, Wood Buffalo National Park.

ing on *Triglochin palustris*), Sandhill Cranes (*Grus canadensis*), Least Sandpipers (*Calidris minutilla*), Western Sandpipers (*Calidris Maori*), American White Pelicans (*Pelecanus erythrorhynchos*), and a Bald Eagle (*Haliaeetus leucocephalus*) observed during the hour-long sample. There were abundant aquatic invertebrates in the flarks. This saline wetland complex appears distinct ecologically from the gypsum-dominated Whooping Crane nesting area. In the latter area, the dominant vegetation types are shrub bog-marsh, mixed marsh, diatom ponds, and shrubby organic terrain; salt marshes are not present (Timoney 1999).

Discussion

While the study area lies geographically within the Continental High Boreal wetland subregion (National Wetlands Working Group 1988), the biota, saline hydrogeology, and minimal peat accumulation in these patterned salt marshes indicate the type to be allied with wetlands of the Aspen Parkland Continental Prairie subregion. The virtual lack of bryophytes and characteristic fen species, the predominance of marsh halophytes, and the prevalence of plants and birds characteristic of the Great Plains (Table 1) indicate these communities are similar to Prairie type intermittent saline lakes, not boreal fens. It is also noteworthy that the Benchmark Creek salt

marshes lie adjacent to true Prairie grassland disjunct occurrences on the south-facing uplands along the creek where *Stipa*, *Agropyron*, and dryland *Carices* dominate on Dark Grey and Black Solods (Schwarz 1994; Schwarz and Wein 1997). Soil observations in the two wetlands bear on the question of whether these communities are salt marshes or fen peatlands (Table 2). The minimal peat accumulation and the predominance of a heavily-gleyed clayey Cg ally the soils with Rego Humic Gleysols (although the surface horizon is Om, not Ah) (classification after Canada Soil Survey Committee 1978). Within the Canadian Wetland Classification System (Zoltai and Vitt 1995), the patterned saline wetlands would classify as a mosaic of tidal marshes and shallow open water. I suggest a new type: interior patterned saline marsh.

Looman (1981) classified saline vegetation in the Canadian prairie provinces. Prairie Bulrush (dominant at Benchmark in August 1994) was represented in six of eight associations and was the dominant species in one association. Kantrud (1996) found that two groups of plants are frequent associates of Prairie Bulrush. The first group includes tall, often long-lived perennial graminoids such as *Phragmites australis* (Reed), *Typha latifolia* (Common Cattail), and *S. acutus* (Great Bulrush) that may shade Prairie Bulrush. The second group of associates includes

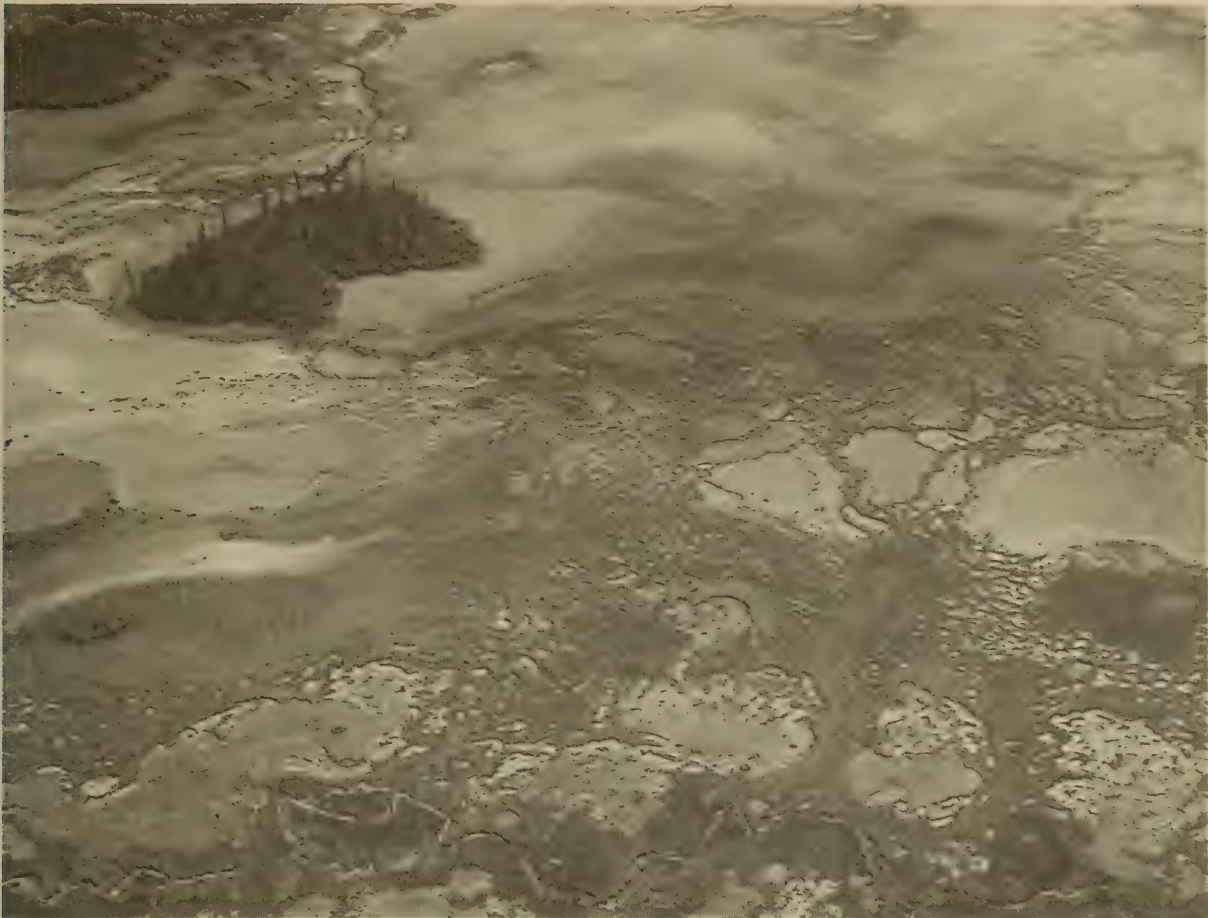


FIGURE 3. Aerial view of string and net-patterns and flarks at Lobstick Creek, 10 August 2001. Photo courtesy Mark Bradley, Wood Buffalo National Park.

TABLE 1. Plant species composition and percent cover values from Benchmark and Lobstick creeks in 20 by 25 m² relevés sampled 10 August 2001. Bold face taxa are common to both sites. Distribution notes are based on Scoggan (1978-1979); Porsild and Cody (1980); Moss (1983); and Kershaw et al. (2001).

Taxa	Benchmark Creek		Lobstick Creek		Distribution Notes
	String	Flark	String	Flark	
<i>Aster pauciflorus</i>	trace	0	0	0	rare and disjunct in northern
Alberta					
<i>Atriplex subspicata</i>	0	0	40	0	at n. limit
Blue-green algae -					
diatom community	0	75	0	100	need documentation
<i>Calamagrostis stricta</i>	60	0	0	0	
<i>Carex mackenziei</i>	01	0	0	0	circumpolar, coastal species;
					first inland record for Canada?
<i>Hordeum jubatum</i>	02	0	01	0	
<i>Amblystegium varium</i>	01	0	0	0	
<i>Monolepis nuttalliana</i>	trace	0	0	0	near northern limit
<i>Plantago maritima</i>	0	0	15	0	uncommon and local
<i>Puccinellia nuttalliana</i>	trace	0	20	0	uncommon in northern Alberta
<i>Scirpus paludosus</i>	0	10	0	0	at northern limit
<i>Spergularia marina</i>	trace	0	trace	0	uncommon and local
<i>Triglochin maritima</i>	10	25	0	0	
<i>Triglochin palustris</i>	trace	0	20	2.5	
Total Vascular Cover	~74	35	96	2.5	
Total Non-vascular Cover	1	75	0	100	

At Benchmark Creek, present outside releve: *Agropyron trachycaulum*, *Aster ericoides* (near northern limit), *Glaux maritima* (uncommon in northern Alberta), *Plantago eriopoda* (uncommon in northern Alberta), *Potentilla anserina*, and *Suaeda calceoliformis* (near northern limit).

TABLE 2. Soil horizon observations at Benchmark and Lobstick Creeks based on 1 m deep soil auger holes.

Location	Soil horizon	Notes
Benchmark Creek String		
0–30 cm	Om	Om graminoid peat; Cg strongly gleyed clay
30–100 cm	Cg	
Benchmark Creek Flark		
0–43 cm	Om	Om a complex of diatomaceous earth and graminoid peat; Cg strongly gleyed clay
43–100 cm	Cg	
Lobstick Creek String		
0–10 cm	Om1	Om1 vascular plant peat; Om ² diatomaceous earth; Cg strongly gleyed clay includes an apparently frozen sand layer at ~86 cm
10–23 cm	Om2	
23–100 cm	Cg	
Lobstick Creek Flark		
0–8 cm	Om	Om diatomaceous earth; Om/Cg = mix of Om with gleyed C; Cg strongly gleyed clay includes apparently frozen sand layer at ~71 cm
8–25 cm	Om/Cg	
25–100 cm	Cg	

Triglochin maritima, *Eleocharis palustris* (Creeping Spike-Rush), *Atriplex patula* (sensu lato), *S. pungens* (Three-Square Rush), *Hordeum jubatum*, and several species of *Juncus*. Increases or decreases in the competitive advantage of these species are related to changes in salinity, elevation, disturbance and inundation regime, substrate texture, and many other factors (Kantrud 1996). Prairie Bulrush marshes tend to contain surface water for shorter periods than do semipermanent fresh or slightly brackish wetlands. The patterned saline wetlands in Wood Buffalo and vicinity belong to Kantrud's second group.

Wallis (1990) noted a *Scirpus paludosus* "saline emergent marsh" type for the Grassland and Parkland region of eastern Alberta. No mention was made of net or string patterns in any of the saline wetlands he studied. Fairbarns (1990) studied saline meadows near High Level, Alberta and made no mention of net or string patterns. He identified a *Scirpus paludosus*-*Eleocharis palustris* type of moderately saline "marsh meadow" and noted that the species was rare in northern Alberta.

I could find no published accounts of boreal patterned saline wetlands, but P. Lee (Global Forest Watch, Edmonton, Alberta, personal communication 1999) called my attention to two such wetlands along the Clearwater River in northeastern Alberta. Clearwater River file notes in the Alberta Natural Heritage Information Centre (Alberta Environmental Protection, Edmonton) indicated a "wet meadow with crescent-shaped ponds" at 56° 40'30" N, 110° 55'W and "spring and crescent-shaped ponds" at 56° 44'30"N, 110°30'W. No vegetation data could be found. A 1:15 000 airphoto of the area showed string patterns in the wetlands. A chemical analysis at one of the Clearwater River saline wetlands (dated 28 March 1984, location not given) reported a pH of 7.9, conductivity of 14.77 mS/cm, and total dissolved solids 8500, chloride 4600, sodium 2940, sulphate 600, bicarbonate 184, calcium 180, and

magnesium 71 mg/l. While such figures classify the wetland as saline, the wetland does not fit within the boreal types described by National Wetlands Working Group (1988), and is most closely-related to their (unpatterned) saline wet meadow and emergent marshes of the Canadian Prairies.

The chemical limnology of some lakes in the area of Benchmark and Lobstick has been described by Moser et al. (1998). Their most similar site, e.g., was lake "WB25", but conductance, sodium, and chloride values were lower by 1–2 orders of magnitude at "WB25". The marshes of Benchmark and Lobstick are likely more saline than the gypsum-dominated sinkhole lakes they described, and also drawdown regularly resulting in widely fluctuating solute concentrations. Chemical profiles of several ponds and springs described by McNaughton (1991) west of Lobstick may be more similar (e.g., "Klewil" where he observed a conductivity of 11.3 mS/cm, somewhat lower values for sodium and chloride and higher values for sulphate and calcium). Chemical data and zooplankton communities were described for one lake near Benchmark Creek (lake SP-CL, 59° 48'N, 112° 01'W) and one lake near Lobstick (lake GL-D, 60° 00'N, 112° 37'W) by Derry (2001). Near Benchmark, she reported a conductivity of 17.6–20.4 mS/cm, Na 3520–4077 mg/l, and Cl 5265–6116 mg/l — very similar to the chemical data from the Clearwater River saline wetlands.

A significant feature of these wetlands is the high proportion of rare or uncommon plant species (Table 1). Most surprising is the occurrence of *Carex mackenziei*, a circumpolar coastal species. Its occurrence at Benchmark may be the first inland record for Canada. *Scirpus paludosus*, *Atriplex subspicata*, and *Aster pauciflorus*, are prairie wetland plants that are rare in northern Alberta.

Little is known of the benthic algal and diatom community. While some characteristic diatoms have been noted from the nearby Whooping Crane nesting

area (Timoney et al. 1997), the water regime and its chemistry may result in a different flora and fauna at Benchmark and Lobstick. Near the headwaters of Benchmark Creek, M. Rosen (personal communication, Fort Smith, Northwest Territories, October 2001) has found the dried mud crust at Grosbeak Lake (59° 47' 30"N, 111° 59'W) to be dominated by blue-green algae, whose matrix contained abundant copepods, nematodes, diatoms, and foraging brine flies.

The three interior patterned saline marshes noted here were associated with creek or river valleys. In addition to saline surface waters, these wetlands may require a slope gradient conducive to gradual surface water flow. String or net formation may be encouraged by peat accumulation or entrainment of laterally-moving mineral or organic matter. Some of the patterns might arise from a patterned ground process associated with excessive soil salts.

Interior patterned saline marshes are groundwater and runoff fed wetlands which undergo large seasonal and annual changes in water level and concentration of solutes. These wetlands, which appear to be rare, may harbor a variety of biota that require better documentation. They merit further study, which I hope will delight all naturalists who visit them.

Acknowledgments

Peter Lee and Lorna Allen made available information on the Clearwater River wetlands. Thanks to Dale Vitt, Bill Last, John Smol, Derek Johnson, and anonymous reviewers for comments. Thanks to Anne Robinson who assisted in August 1994 fieldwork; to Catherine England who identified the moss, and to Mark Bradley who assisted in the August 2001 fieldwork and identified the birds at Lobstick. Thanks to Wood Buffalo National Park fire management who provided the helicopter access to Lobstick. This paper is dedicated to my late friend Steve Zoltai who would have liked these wetlands.

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Predation on Nesting Woodpeckers in British Columbia

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Predation on eggs, nestlings, and breeding adults of Red-naped Sapsuckers, *Sphyrapicus nuchalis*, Northern Flickers, *Colaptes auratus*, Hairy Woodpeckers, *Picoides villosus*, and Williamson's Sapsuckers, *S. thyroideus*, was documented in the Hat Creek valley, south-central British Columbia from 1989–1994. Predation by Black Bears (*Ursus americanus*), Deer Mice (*Peromyscus maniculatus*), and House Wrens (*Troglodytes aedon*) was observed; and predation by Long-tailed Weasels (*Mustela frenata*) was inferred.

Key Words: Red-naped Sapsucker, *Sphyrapicus nuchalis*, Williamson's Sapsucker, *S. thyroideus*, Hairy Woodpecker, *Picoides villosus*, Northern Flicker, *Colaptes auratus*, Black Bear, *Ursus americanus*, Deer Mouse, *Peromyscus maniculatus*, House Wren, *Troglodytes aedon*, nesting, predation, British Columbia.

Hole nesting in birds has evolved independently in many taxonomic groups. The generally accepted dogma is that hole nesting offers an advantage over open nesting (e.g., von Haartman 1957). Many authors (e.g., Lack 1954; Nice 1957) have provided evidence to suggest that nesting success is higher in hole-nesting species even though there is more constraint on choice of nesting location. Because predation can be a major cause of nest failure among species that nest in holes (Nilsson 1984), it has obvious implications for the evolution of life history traits (Martin 1995). Predation, therefore, must be a strong evolutionary force with respect to breeding biology (Alerstam and Högstedt 1981; Nilsson 1984). However, data concerning predation on hole-nesting species are difficult to obtain, requiring detailed life-history studies over successive breeding seasons (Greene 1986); and usually involve climbing trees, many of which are in various stages of decay. Recent advances in technology have allowed some researchers to utilize cameras to circumvent some of the problems associated with observing nests (e.g., Martin 1988; Picman and Schriml 1994; Thompson et al. 1999). The use of cameras for tree holes that are relatively high or for observing nocturnal predators, however, is still quite limited. Besides difficulties associated with nest monitoring, many studies of the reproductive success of hole-nesting species have relied upon nest box studies (e.g., van Balen and Potting 1990; Verhulst et al. 1995) rather than using natural cavities.

Our objectives are to document predation events, to identify the predators, and to describe the evidence that allows inferences about the species of predator that prey upon woodpecker nests. In this paper we define nest predation as any event that

results in the destruction of eggs or the death of a chick or adult during the nesting stage without regard to whether the “predator” actually ingested the egg, chick, or adult (cf. Sealy 1994). Under this definition, a predator may be motivated either by hunger or by a desire to obtain a nest or roost site.

Study Area and Methods

The study site was within the Hat Creek valley near Upper Hat Creek (25 km SW of Cache Creek), south-central British Columbia (50°46'N 121°38'W), at an elevation of approximately 1200 m. The slopes of the narrow valley are forested with second-growth Interior Douglas-fir (*Pseudotsuga menziesii*), Interior Spruce (*Picea engelmannii* × *glauca*), and pines (*Pinus contorta* and *P. ponderosa*), with some Trembling Aspen (*Populus tremuloides*). On the valley bottom the same tree species occur, but aspen and willow (*Salix* spp.) are more abundant. Further details about the study site are given by Walters (1996).

Woodpecker nests were studied from late April to late July 1989–1994. Nest monitoring varied among years. In 1989 and 1991, nests were monitored up to three times; in 1990 and 1992, they were visited approximately 20 times; and in 1993 and 1994, nests were visited daily. Emphasis was on finding nests of the Red-naped Sapsucker (*Sphyrapicus nuchalis*), the most abundant breeding species in the area. Other common breeding woodpeckers were the Northern Flicker (*Colaptes auratus*), Hairy Woodpecker (*Picoides villosus*), and Pileated Woodpecker (*Dryocopus pileatus*). Downy Woodpeckers (*Picoides pubescens*) and Williamson's Sapsuckers (*Sphyrapicus thyroideus*) bred regularly in the area but were uncommon.

Nests were found by various means: nesting signs

(e.g., recent excavations, wood chips on ground), audible cues (e.g., drumming, vocalizations, nestling calls), observing adults feeding young, or by direct observations of birds (Jackson 1977). In 1992-1994 we checked nest contents with a mirror and flash-light (nest contents were not checked prior to 1992). Predation was assumed when all eggs or nestlings were missing from the nest (except when fledging was expected), or if eggshells, feathers, or other signs (e.g., sticks in the hole entrance) were in the nest cavity or on the ground below the nest (Johnsson 1994). The identity of the predator was determined by either observation of the predation

event or indirectly by examining the result of the predation event (e.g., use of sticks by wrens, bear claw marks). All of our observations of predation events were opportunistic in nature and occurred while we were checking the status of each nest.

Results

The number of woodpecker nests monitored varied among years (Table 1). We found evidence of 23 cases of nest predation out of a total of 239 nests during our study: probable mustelid, 12; Black Bear (*Ursus americanus*), 4; House Wren (*Troglodytes aedon*), 3; Deer Mouse (*Peromyscus maniculatus*),

TABLE 1. Numbers of woodpecker nests with eggs or young and the outcome associated with each.

Species	Year	Total	Cause of Failure					Outcome	
			Predation				Unknown	Successful	Unknown
			Weasel	Bear	Mouse	Wren			
RNSA	1989	39	—	—	—	—	—	—	39
	1990	36	—	—	—	—	3	22	11
	1991	19	—	—	—	—	—	—	19
	1992	24	1	—	—	—	1	21	1
	1993	25	2	—	1	—	2	20	—
	1994	30	3	—	—	3	5	19	—
NOFL	1989	1	—	—	—	—	—	—	1
	1990	9	—	1	—	—	1	3	4
	1991	2	—	—	—	—	—	—	2
	1992	11	1	2	1	—	2	—	5
	1993	9	1	—	—	—	—	7	1
	1994	11	2	—	1	—	1	7	—
HAWO	1989	3	—	—	—	—	—	—	3
	1990	3	—	—	—	—	—	1	2
	1991	0	—	—	—	—	—	—	—
	1992	3	1	—	—	—	—	2	—
	1993	2	1	—	—	—	—	1	—
	1994	3	—	—	—	—	—	3	—
WISA	1989	1	—	—	—	—	—	1	—
	1990	0	—	—	—	—	—	—	—
	1991	1	—	—	—	—	—	—	1
	1992	1	—	1	—	—	—	—	—
	1993	0	—	—	—	—	—	—	—
	1994	0	—	—	—	—	—	—	—
DOWO	1989	0	—	—	—	—	—	—	—
	1990	1	—	—	—	—	—	1	—
	1991	0	—	—	—	—	—	—	—
	1992	1	—	—	—	—	—	—	1
	1993	0	—	—	—	—	—	—	—
	1994	1	—	—	—	—	—	1	—
PIWO	1989	0	—	—	—	—	—	—	—
	1990	0	—	—	—	—	—	—	—
	1991	0	—	—	—	—	—	—	—
	1992	0	—	—	—	—	—	—	—
	1993	1	—	—	—	—	1	—	—
	1994	2	—	—	—	—	1	1	—
Total		239	12	4	3	3	17	110	90

RNSA = Red-naped Sapsucker; NOFL = Northern Flicker; HAWO = Hairy Woodpecker, WISA = Williamson's Sapsucker, DOWO = Downy Woodpecker, and PIWO = Pileated Woodpecker.

3; and Cooper's Hawk (*Accipiter cooperii*), 1. We also found 17 nests where the young died of unknown causes.

Twelve occurrences of nest predation (six Red-naped Sapsucker, four Northern Flicker, two Hairy Woodpecker) were presumed to be by a mustelid, probably the Long-tailed Weasel (*Mustela frenata*) given that it was the only mustelid observed in the study area. Killed were both adult woodpeckers and large nestlings, all within nesting cavities. In the first case of predation on sapsuckers, some hairs (light brown in colour and >3 cm) were found at the cavity entrance and the eggs were gone. In the second, shell fragments were observed within a sapsucker cavity followed by a dead adult male in the cavity the next day. The third event occurred when a large sapsucker nestling was found partly eaten at the base of a nest tree. In the fourth, flesh plus crushed shells were present in the sapsucker nest. The fifth nest was observed late in the day as both parents were feeding the young. Early the following day the male was gone and the chicks were found dead in the cavity. Finally, of three sapsucker nestlings within a few days of fledging, one was found dead in the nest and the others alive at the base of the nest tree. The dead

chick was removed, and the live chicks were returned to their nest. The next day one chick was dead inside the cavity and the other chick was alive at the base of the nest tree. We placed this chick on the trunk of the tree; it fledged successfully. Three adult Northern Flickers were depredated while incubating or brooding. Hairy Woodpecker adult males were preyed upon at night when brooding large young. Both nests were in the same tree in successive years. In each case at least one of the young was removed from the cavity. Nine of the twelve nests where suspected mustelid predation occurred were from two areas (<5 ha) within our 80 ha study site. In all nests where mustelid predation is suspected, no tooth marks were evident around the cavity entrance.

Evidence of predation or attempted predation by Black Bears was of three types: fresh scarring of trees by claws; scarring around nest holes by teeth; and mortality of chicks or adults. Many old nest trees (10/25 in 1993 and 11/30 in 1994 for Red-naped Sapsuckers) had numerous scars caused by the claws of bears during climbing (Figure 1). We noted four instances where apparently successful predation by bears had occurred and eight more attempts. In one case, a low (approximately 1.5 m above ground) Northern Flicker nest in a rotten stub of a large Interior Spruce had been exposed when the stub was ripped open. Bloody pinfeathers (remiges) of the nestlings were around the base of the stub. The tall grass around the stub was beaten down, suggesting the presence of a large mammal, and fresh bear feces lay a few meters away. In another case, a Williamson's Sapsucker nested in a Trembling Aspen 1.8 m above the ground. When the nest was checked, bite marks (consistent with a bear) were evident around the entrance (Figure 2) and the remains of the incubating male were in the intact nest cavity. We also found six Red-naped Sapsucker nests, one Northern Flicker nest, and one Hairy Woodpecker



FIGURE 1. Portion of a Trembling Aspen trunk used for nesting by Red-naped Sapsuckers over many seasons. Note the extensive scarring on the trunk, caused by Black Bears climbing up the tree.



FIGURE 2. Nest hole of Williamson's Sapsucker, showing marks from lower canines of Black Bear; the adult male died in the nest cavity from injuries received from the bear.

nest in which a bear had climbed to the cavity and clawed at the entrance but was not successful in gaining access to the nest. The nests had been checked less than 24 hours earlier.

We observed one occurrence of egg predation by a Deer Mouse and suspected it in two other nests. A female Northern Flicker flew and called agitatedly as we checked her nest. A Deer Mouse was visible in the nest, amidst the eggs, and two of the six eggs were smashed. Six hours later the entire clutch had been destroyed and only broken, flattened eggshells remained. Single nests of a Northern Flicker and a Red-naped Sapsucker were found with broken and flattened full or partial clutches in the cavity.

House Wrens depredated three Red-naped Sapsucker nests. At one, eggshell fragments were inside and outside the nest cavity. The next day, House Wrens were observed entering and exiting the cavity and there were twigs in the cavity (no twigs were present the day before). Two other predation events occurred such that freshly dead Red-naped Sapsucker chicks were found in their nests, sticks over them, and House Wrens were nearby. In all cases, House Wrens later nested within the sapsucker cavities.

One instance of predation of an adult Red-naped Sapsucker by a Cooper's Hawk was observed. The radiotagged sapsucker, five days after successfully fledging four young, was found dead in a Cooper's Hawk nest.

Discussion

In spite of any extra protection afforded cavity nesters, woodpeckers in our study suffered substantial losses in the breeding season. We cannot, however, estimate the proportion of nests that were depredated because nest-monitoring effort differed among years.

Evidence suggested that mustelids may be the most common predators of woodpecker nests in our study area. In England, almost all (96%) of the predation on tit (*Parus* spp.) nests in nest boxes was by mustelids (Dunn 1977). Sleeman (1993) even speculates that many hole-nesting fauna found in Britain are not found in Ireland because of predation pressure by *M. erminea*. Of known predation events in our study, we attribute 55% to mustelids; but one would expect relative abundances of predators to vary among geographic areas. For example, in Sweden, woodpeckers were the chief predator (48%) of tits nesting in nest boxes (Nilsson 1984).

Interestingly, presumed predation by mustelids occurred in certain parts of our study area from year to year. Individual mustelids learn where nests are (Johnson 1947) and revisit them from one year to another (Sonerud 1985a,b; 1989). This may explain what we attribute to mustelid predation in our study, and why (in some species) nestling predation in new

cavities may be less than in old ones (Nilsson et al. 1991). Because mustelids in our study area tend to be nocturnal (Burt and Grossenheider 1980; but see Johnson 1947; Pettingill 1976; Kilham 1977b; and Daily 1993) and our nest monitoring was diurnal, we are not able to state conclusively that mustelids were responsible for the predation events we attributed to them. However, we found hairs at the entrance to the cavity in one case similar to what Kilham (1977b) reported after he had observed a weasel depredating a Yellow-bellied Sapsucker (*Sphyrapicus varius*) nest. In contrast, Crockett (1975, page 93) observed "the total destruction" of a Williamson's Sapsucker nest by *M. frenata*. Similarly, Erskine and McLaren (1972) report several Northern Flicker nests that were destroyed by assumed *M. erminea*.

Successful predation by Black Bears on nesting adult Red-naped Sapsuckers and Northern Flickers has been reported by Franzreb and Higgins (1975) and DeWeese and Pillmore (1972), respectively. Similar to some of the nests in our study, the latter authors noted that bears gained entrance to nest cavities in living aspen. How Black Bears capture adult woodpeckers and probably advanced nestlings is largely unknown. Dixon (1927) reported a Black Bear trying to gain access to a Black-backed Woodpecker (*Picoides arcticus*) nest by gnawing at the entrance hole. Our Williamson's Sapsucker observation suggested that the bear gnawed at the nest entrance and caught the inhabitant as it exited. Adults and advanced nestlings are prone to scramble out of the nest when disturbed (e.g., by a human climbing the nest tree). Northern Flickers are particularly susceptible to predation by bears at our field site, as Northern Flickers nest close to the ground in rotten snags. Because it has been assumed that hole nesting offers a refuge against predation (Lack 1968), Redondo and de Reyna (1988) claimed that the young of hole-nesting species produce calls with wider frequency ranges and less attenuable signals than those of open-nesting species (cf. Popp and Ficken 1991). The incessant calling of young in some species may be a cue to which Black Bears (and other predators) are attuned and thus a paradox seems apparent. Counter to the views of Redondo and de Reyna (i.e., ecological release of nestling vocalization), perhaps the vocal cues emitted by the young of hole-nesting species are constrained such that the signal will carry outside of the nest (i.e., so the parents can hear the young). It does not appear that Black Bears randomly climb trees. We compared the frequency with which available trees (i.e., > 12 cm diameter at breast height) in a 1 ha area surrounding the nest tree (N = 17) exhibited bear claw marks compared with nest trees. Frequency of bear claw marks differed significantly (Fisher's Exact Test, $p < 0.001$) between nest trees (11 / 30 Red-naped Sapsucker nests in 1994) and available trees

(190 / 4155), suggesting that bears are selectively climbing nest trees.

Deer Mice have been reported to be significant predators on ground-nesting birds (Maxson and Oring 1978; Reitsma et al. 1990). However, we are only aware of one study that reported predation by *Peromyscus* spp. on a hole-nesting species: Guillory (1987) observed predation by *P. leucopus* and *P. gossypinus* on Prothonotary Warbler (*Protonotaria citrea*) nests. Our findings of Deer Mice predation appear to be the first for a woodpecker nest. We estimate that at least 14% of our predation events were due to Deer Mice.

House Wrens often peck at and perforate eggs, in conspecific and heterospecific nests, and then remove them (White and Kennedy 1997). One adaptive interpretation (among several) placed on this behavior is that it is an interference mechanism (Belles-Isles and Picman 1986). In our study, House Wrens benefited through such behavior by disrupting the nesting cycle of Red-naped Sapsuckers, who abandoned their nesting attempt, or spent more time away in preparation for another breeding attempt. In the latter case, sapsucker re-use of the nest cavity was discouraged because the wrens put nesting material in the cavity. Kennedy and White (1992) have noted the discouraging effect of sticks on other species. We suspect that the placement of nesting material (e.g., sticks) on sapsucker nestlings within our study may have caused their death.

Other species may have been responsible for the unknown cases of predation. For example, both Red Squirrels (*Tamiasciurus hudsonicus*) and Northern Flying Squirrels (*Glaucomys sabrinus*) are present in the study area. The former is known to depredate Yellow-bellied Sapsucker nests (Lawrence 1967; Erskine and McLaren 1972) but we have no evidence (e.g., none of the depredated nests was chewed around the entrance hole) to suggest that squirrels depredated any nests. In fact, we had several nest trees where both squirrels (*T. hudsonicus* and *G. sabrinus*) and sapsuckers coexisted without any apparent negative effect on the sapsucker nests. Although Raccoons, *Procyon lotor*, are known to prey upon Yellow-bellied Sapsucker nests (Kilham 1971, 1977a), they do not occur in our study area.

We have outlined the nature of predation events on four woodpecker species, all of which excavate cavities in which to nest. Given the extent to which these cavity nesters are susceptible to predation may lead one to question the adaptiveness of hole nesting as an anti-predation strategy. As some have suggested (e.g., Alerstam and Högstedt 1981), perhaps hole nesting is the ancestral trait and open nesting is derived. Thus, open-nesting species that are secretive in their foraging might overcome the risk of predation relative to the cost of finding or constructing a suitable hole in which to nest. Under this scenario,

hole-nesting species are not seeking refuge from predatory events but, in fact, have less chance of being depredated than if they were to become open nesters. Lack (1954) and Nice (1957) both estimated that the proportion of eggs in completed clutches that give rise to flying young was approximately 45-46% in open-nesting species compared with 66-67% in hole-nesting species. One would expect predation to be lower in hole-nesters that excavate within relatively hard trees as opposed to species that use softer wood. Supporting this contention is the work of Christman and Dhondt (1997) who found that nest predation in Black-capped Chickadees (*Poecile atricapilla*), a species that excavates within soft and often rotten wood, is as high as 62%. In our study, Northern Flickers tended to nest in softer trees, and we recorded a predation event in 21% of our nests. On the other hand, Red-naped Sapsuckers tended to nest in live aspen (i.e., relatively hard wood; Schepps et al. 1999), and we recorded a predation event in only 6% of those nests. Neither figure should be interpreted as overall predation frequency because the number of nest observations differed from year to year. Besides the integrity of the substrate, Northern Flickers may have been exposed to higher predation rates than sapsuckers because the cavity entrance of Northern Flicker nests is larger. Several researchers (e.g., Sandström 1991; Sonerud 1985b) found that cavities with larger entrance holes were more prone to predation. Ironically, Martin and Li (1992) did not observe *any* predation on Northern Flicker or Red-naped Sapsucker nests during three breeding seasons in Arizona. We hypothesize that this finding may be due to the fact that their site differed from ours with respect to potential predators (e.g., the Arizona field site had less bears, personal observation (ELW)) and cavity-nesting species tended to nest higher in trees in Arizona (i.e., reducing potential for depredation, personal observation (ELW)). In fact, Li and Martin (1991) reported that nest success was lower for species with lower nest height in their study area.

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Timing of Pregnancy, Lactation, and Female Foraging Activity in Three Species of Bats in Southern Illinois

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Pregnant Northern Long-eared Bats (*Myotis septentrionalis*), Red Bats (*Lasiurus borealis*), and Eastern Pipistrelles (*Pipistrellus subflavus*) were taken beginning in mid-May in southern Illinois. For Northern Long-eared and Red Bats, pregnant individuals were caught during a two-week period until early June. Pregnancy and lactation in Northern Long-eared and Red Bats were fairly synchronized; both species apparently limited their foraging activity during a one-week period possibly near and immediately after parturition. Pregnancy in Eastern Pipistrelles was much less synchronized. Capture of pregnant females extended over at least an eight-week period from mid-May to mid-July. Volant juvenile Northern Long-eared Bats were taken three weeks earlier than any other species; either parturition was earlier or young developed more rapidly. Pregnant Northern Long-eared Bats foraged primarily in the early evening; early and late activity periods were evident for lactating individuals. Foraging trends for pregnant and lactating Red Bats and Eastern Pipistrelles were less apparent. Significant differences in body mass of Northern Long-eared Bats and Eastern Pipistrelles were evident based on reproductive status. No differences in body mass associated with reproductive condition were found in female Red Bats.

Key Words: Eastern Pipistrelle, *Lasiurus borealis*, mist netting, *Myotis septentrionalis*, Northern Long-eared Bat, *Pipistrellus subflavus*, Red Bat, reproduction.

Bats in southern Illinois are seasonally monestrous and give birth during the late spring and early summer when insect populations are most abundant. Despite increased research, there is little quantitative information on the timing of pregnancy and lactation for many species of bats. Hoffmeister (1989), for example, notes time of parturition for many species simply as “late June or early July.” We collected information on temporal patterns of pregnancy and lactation for species of bats mist netted throughout southern Illinois during a study on the maternity roosting ecology of Indiana Bats (*Myotis sodalis*). Specifically, we discuss the first and last dates of capture for pregnant and lactating adult Northern Long-eared Bats (*Myotis septentrionalis*), Red Bats (*Lasiurus borealis*), and Eastern Pipistrelles (*Pipistrellus subflavus*), species-specific differences in body mass of pregnant, lactating, and nonpregnant females, timing of nightly foraging activity, and the first date volant juveniles were netted.

Methods and Materials

The study was conducted throughout the 109 263-ha Shawnee National Forest in southern Illinois. We selected a variety of sites to capture bats based on a range of habitat variables obtained from the Southern Illinois University GIS database and the Illinois State Geological Survey.

Mist netting was conducted on a total of 41 sites from 18 May through 18 August 1999, and from 12 May through 20 July 2000. We used nets and associ-

ated equipment as described by Gardner et al. (1989). Nets were placed along streams or other areas of anticipated high bat activity, as well as within closed canopy interior forest sites. A minimum of two nets 5.6 m or higher, was used for two consecutive nights when they were set over a water source. When nets were not set above water, four sets 5.6 m or higher were operated for two consecutive nights. Nets were stacked up to three high (9 m) with various widths to enclose the flight corridor (Gardner et al. 1989). Netting began at dusk and usually continued until 0200 h the next morning, with nets checked every 20 minutes. Criteria for site selection and the netting protocol are described in Carroll (2001) and Carroll et al. (2002).

Pregnant females were identified by palpation of their abdomen; lactation was evident by condition of the nipples (Foster and Kurta 1999; Kunz 1973; Racey 1988). Juveniles and adults were distinguished by examination of phalangeal epiphyses, overall body size, condition of teats in females, and size of testes in males (Anthony 1988). Bats were weighed to the nearest 0.5 g. A 3 mm circular punch in each wing was used to collect tissue for genetic analyses and also served as a semi-permanent mark to determine recaptures. Forage activity periods were based on the time of captures, with each six-hr mist netting session grouped into three two-hr periods.

Results

Mist nets were operated a total of 339 net nights

TABLE 1. Species of bats, number of individuals mist netted, and the earliest date volant juveniles were caught, at 41 sites throughout Shawnee National Forest during spring and summer 1999 and 2000.

Species	Number of Individuals	Earliest Date Volant Young
Northern Long-eared Bat (<i>Myotis septentrionalis</i>)	174	25 June
Red Bat (<i>Lasiurus borealis</i>)	75	13 July
Eastern Pipistrelle (<i>Pipistrellus subflavus</i>)	73	15 July
Big Brown Bat (<i>Eptesicus fuscus</i>)	31	15 July
Evening Bat (<i>Nycticeius humeralis</i>)	20	15 July
Indiana Bat (<i>Myotis sodalis</i>)	14	7 July
Little Brown Bat (<i>Myotis lucifugus</i>)	13	17 July
Southeastern Bat (<i>Myotis austroripareus</i>)	10	17 July
Hoary Bat (<i>Lasiurus cinereus</i>)	4	—
Silver-haired Bat (<i>Lasionycteris noctivagans</i>)	3	—

during the two years of sampling. A total of 10 species and 417 individual bats was captured (Table 1). Only two individuals were recaptured. Because equal numbers of bats were captured each year, we combined data from both years, with analyses limited to Northern Long-eared Bats, Red Bats, and Eastern Pipistrelles based on sample sizes.

Timing of Pregnancy, Lactation, and Volant Juveniles

Northern Long-eared Bats – Pregnant females were taken from 16 May through 2 June. Lactating females were captured from 5 June through 20 July. During the period when pregnant females were no longer taken, but before lactating bats appeared (3-8 June 1999 and 31 May-5 June 2000), females appeared to limit their foraging activity. We netted 13 male *M. septentrionalis* during these two periods, but no females ($\chi^2 = 13.00$, $P < 0.001$). Of 41 adult females netted during May and June, 40 (97.6%) were either pregnant or lactating. The only adult considered non-pregnant was taken on 12 May. From 2 July until the end of fieldwork, only 4 of 26 females (15.4%) cap-

tured were still lactating. The mean body mass of 20 pregnant females was 7.99 g. This was significantly heavier than the body mass of 32 lactating individuals ($\bar{x} = 7.05$ g; $t = 2.86$, $P = 0.01$), as well as 28 nonpregnant adult females captured after the reproductive season ($\bar{x} = 6.73$ g; $t = 5.04$, $P < 0.0001$). The first volant juveniles were netted on 25 June; 20 days after the earliest lactating females were taken.

Red Bats – Pregnant females were taken from 15-30 May. Lactating females were netted from 5 June through 7 July. As with *M. septentrionalis*, female Red Bats also apparently limited activity during the week between captures of the last pregnant individuals and the first females that were lactating. Only eight Red Bats were taken during this period; seven were males ($\chi^2 = 4.50$, $P < 0.05$). The mean body mass of 13 pregnant Red Bats (16.4 g) was not significantly heavier than that of nine lactating individuals ($\bar{x} = 14.1$ g; $t = 2.03$, $P = 0.076$). Volant young were first taken on 13 July, three weeks after Northern Long-eared Bats, and 38 days after the earliest lactating females were taken.

TABLE 2. Number of female bats mist netted during each of three 2-hour time periods, based on reproductive condition, on Shawnee National Forest, southern Illinois, during spring and summer 1999 and 2000.

Species/ Reproductive Condition	Time Periods Captured		
	20:00-21:59	22:00-23:59	24:00-02:00
Northern Long-eared Bat			
Pregnant	18	2	0
Lactating	12	8	13
Nonpregnant	12	10	3
Red Bat			
Pregnant	8	5	1
Lactating	5	3	1
Nonpregnant	1	0	0
Eastern Pipistrelle			
Pregnant	13	4	7
Lactating	7	3	3
Nonpregnant	5	4	3

Eastern Pipistrelles – Pregnant females were taken throughout an eight-week period from 19 May through 17 July. Lactating females were taken from 25 June through 17 July. Lactation in Eastern Pipistrelles in southern Illinois continues well into August given that pregnant individuals occurred as late as 17 July. However, we did not take any later than this during the first field season, even though netting continued until mid-August. The mean body mass of 21 pregnant females was 7.43 g, not different than the body mass of 10 lactating individuals (6.7 g; $t = 1.44$, $P = 0.182$). Considered together, Pipistrelles that were either pregnant or lactating had a greater mean body mass than six nonpregnant females taken following the reproductive season ($\bar{x} = 6.67$ g; $t = 4.03$, $P = 0.01$). Volant young were first netted on 15 July. As in Northern Long-eared Bats, this was 20 days after the earliest lactating females were taken. Volant young *P. subflavus* emerged about the same time as Red Bats and most other bat species (Table 1) we took in southern Illinois.

Female Foraging Activity Periods

Based on reproductive condition, trends were evident in the timing of foraging activity for some species (Table 2). Pregnant Northern Long-eared Bats were taken significantly more often early in the evening ($\chi^2 = 29.14$, $P < 0.0001$), with no individuals mist netted after midnight. Within the time frame we mist netted each evening, a bimodal activity pattern was evident for lactating Northern Long-eared Bats, with reduced activity from 2200 – 2400 h, although the differences were not statistically significant ($\chi^2 = 5.63$; $0.05 < P < 0.10$). Trends were less apparent for Red Bats and Eastern Pipistrelles, although a bimodal activity pattern was also suggested for pregnant Pipistrelles ($\chi^2 = 5.24$; $0.05 < P < 0.10$).

Discussion

Cause and effect in the timing of reproductive events in mammals often is difficult to identify because of the interrelationships of numerous life history characteristics. This is especially true of bats because they do not fit the typical reproductive pattern for similar-sized terrestrial mammals. Bats have small litter size, relatively long gestation, and large neonatal body mass (Kunz and Hood 2000). Lactation is particularly demanding energetically. As noted by Racey (1982: 63) “. . . adequate food supply during lactation and weaning is the most important selection pressure in the timing of mammalian reproductive cycles.” Vespertilionids in Illinois, because they are insectivorous, are ultimately constrained reproductively by the seasonality of insect abundance. Thus, pregnancy and lactation must be timed to coincide with the abundance of energy available in the spring and early summer (Racey and Entwistle 2000).

Some early information on the timing of reproduction in Northern Long-eared Bats is anecdotal (Brandon 1961; Easterla 1968). Most investigators report later breeding dates in *M. septentrionalis* than we found. For example, Kunz (1971) found pregnant females in central Iowa from 20 May until 23 June, 3 weeks later than we did. He also reported the first volant young occurred on 23 July — a month later than we took them. Whitaker and Hamilton (1998: 101) stated for this species that “. . . the single young is often born in July, or later than in most other eastern U. S. bats.” Lactating females in South Dakota (Turner 1974) were taken in mid-August, a month later than we found them. There appears to be much geographic variation in the timing of pregnancy and lactation in Northern Long-eared Bats, with more northern populations active later than in southern Illinois.

Based on previous studies, less variation may occur in the timing of reproductive events in Red Bats (Shump and Shump 1982) than in Northern Long-eared Bats. Hoffmeister (1989) reported that parturition occurs in late May or early June in Illinois, which coincides with when we found pregnant females. Similar timing is reported for the adjacent states of Kentucky (Barbour and Davis 1974) and Missouri (Schwartz and Schwartz 1981).

Parturition and lactation in *P. subflavus* in southern Illinois was much less synchronized than in Northern Long-eared or Red Bats. Reduced body size and roost temperatures are two strong selection pressures for synchrony of parturition (Tuttle and Stevenson 1982). Because they are smaller than Red Bats and more affected by ambient temperature, Eastern Pipistrelles could be expected to come out of hibernation later, with associated effects on ovulation, pregnancy, and lactation (Racey 1982). Later initiation of reproductive activity and high synchrony was not the case in southern Illinois, however, although it may occur in populations at higher latitudes (Lane 1946; Davis 1963; Fujita and Kunz 1984). We first encountered pregnant Eastern Pipistrelles about as early as Northern Long-eared and Red Bats, but also took them much later in the summer, as was the case with lactating females. Young Eastern Pipistrelles begin to forage by the time they are one month of age (Fujita and Kunz 1984). We took juveniles in mid-June, suggesting parturition occurred in mid-May. Given the lengthy period during which pregnant and lactating Pipistrelles were taken, it is not surprising that there was no apparent week-long cessation of foraging activity as noted in female Northern Long-eared and Red Bats.

The activity patterns we noted for pregnant and lactating females of each species are typical of vespertilionids in temperate regions, and insectivorous bats generally (Erkert 1982). For example, Kunz (1974) reported that pregnant Cave Myotis (*Myotis velifer*) in south-central Kansas emerged to forage

before lactating females. Feeding activity was bimodal with a secondary period prior to sunrise. A later secondary foraging period probably occurred with our populations too; however, we ended mist netting at 0200 h prior to the second peak. Bimodal foraging of lactating bats, suggested most strongly in our study for Northern Long-eared Bats, also might be expected because most bat species return to their roost during the night to suckle young (Racey 1982) and are not available to mist net.

Significant differences in body mass of Northern Long-eared Bats were evident based on reproductive status. Considered together, pregnant and lactating Eastern Pipistrelles also were heavier than nonreproductive females. Conversely, no differences in body mass associated with reproductive condition were found in female Red Bats, the largest of the three species. We suspect our results are influenced by a number of interacting selective factors, including the relationship between adult body mass and neonatal size and litter size, as well as wing loading and associated aerodynamic constraints on flight and foraging ability (Hayssen and Kunz 1996; Kunz and Hood 2000).

Size is also a factor determining when young bats first became volant, as is roost temperature (Tuttle and Stevenson 1982). The 38-day time period to volancy we estimated in juvenile Red Bats was almost twice as long as the 20-day period for juvenile Northern Long-eared Bats and Eastern Pipistrelles. Like most species of bats, *M. septentrionalis* have singleton litters. Eastern Pipistrelles usually have twins, whereas Red Bats have litters of 3-4 pups, one of the largest litter sizes in bats (Hayssen et al. 1993). Neonates of Northern Long-eared Bats and Pipistrelles probably develop faster because with smaller litters, they are born at a relatively advanced size. Smaller species also produce relatively larger young (Tuttle and Stevenson 1982; Hayssen and Kunz 1996). Even if only one or two of the Red Bat pups in a litter survive to volancy, it still takes them longer because they are relatively small at birth.

Because this project was not designed specifically to study reproduction, pregnant females may have been flying earlier in the spring than when we began mist netting. Nonetheless, even had we started earlier, we probably would not have been able to detect females in the earliest stages of pregnancy by palpation. Our field seasons certainly encompassed the last dates of pregnancy and the duration of the lactation period for each species.

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Breeding Bird Declines in the Boreal Forest Fringe of Western Canada: Insights from Long-term BBS Routes

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We examined North American Breeding Bird Survey (BBS) data for five routes affected by loss and fragmentation of local forest habitat and drainage or degradation of wetlands. We focused on the Brightsand, Saskatchewan (1979–1996) route since it once recorded the highest species richness for routes in Canada and has now dropped dramatically. We also examined other routes, Athabasca, Alberta (1972–1996), Two Hills, Alberta (1972–1996), Clouston, Saskatchewan (1973–1996), Tyndall, Manitoba (1971–1996), and one route located (as a control) in contiguous forest at Bird River, Manitoba (1976–1996), to determine how changes in land use influenced relative abundance and diversity of bird species. Over the 18-year history of the Brightsand route, species diversity declined from a maximum of 105 species in 1987 to 67 species in 1995. In addition, 43 species recorded regularly prior to 1990, have disappeared, and 13 other species showed significant negative population trends. This pattern was also seen in Athabasca and Tyndall, as population trends for eight species declined, as did four species on the Two Hills and Clouston routes between 1971 and 1996. Analysis of land cover data along the Brightsand BBS route indicated a 48 to 55% loss of forest cover from 1963 to 1994. Significant declines were not restricted to a particular guild of birds, as forest, grassland and wetland species all declined. In contrast, none of the species on the Bird River control route showed significant population declines. We conclude that habitat loss, due primarily to forest clearing and wetland drainage and modification for agriculture in the forest fringe region of the Canadian prairies, has contributed to the decline of species and disappearance of others on several BBS routes.

Key Words: Breeding Bird Survey, species declines, forest loss, habitat fragmentation, Manitoba, Saskatchewan, Alberta.

The forested regions of the Aspen Parkland and the Boreal Forest Transition zone (Acton et al. 1998) host breeding bird communities among the most diverse in North America (Robbins et al. 1986; Price et al. 1995). The amount of natural habitat available to birds and other wildlife in this area is decreasing, however, as forest land is being converted for agriculture, the remaining forests are fragmented, and wetlands are drained. Estimates using Landsat TM imagery of the southern boreal mixedwoods of Saskatchewan showed the rate of deforestation in the last 20 years as approximately 1.3% per year; which exceeds the world average (Fitzsimmons et al. 1997*; Hobson and Van Wilgenburg, unpublished data). The effect of such habitat loss on bird communities is difficult to assess because few long-term datasets exist (Kirk et al. 1997). The North American Breeding Bird Survey (BBS), however, is a source of long-term data that may provide insight into population trends at various temporal and geographic scales (Sauer et al. 1997*).

The BBS, is a roadside survey with more than 4100 permanent routes many of which are surveyed annually in early summer. Each route is 39.4 km (24.5 miles) long, with 3-minute point counts conducted at 0.8 km (0.5 mile) intervals for a total of 50 point-count stops. All birds seen or heard within a 0.4 km (0.25 mile) radius of each stop are recorded. These surveys begin 30 minutes before sunrise and

normally require 4–5 hours for completion (Sauer et al. 1997*). We examined data from five long-term BBS routes in Alberta, Saskatchewan and Manitoba in order to evaluate the effects of local habitat changes, particularly forest loss, on breeding bird communities. Four of these areas had undergone substantial forest clearing and fragmentation. We contrast these data with a single long-term BBS route located in continuous forest.

The BBS was originally designed to monitor population change at broad levels. Several factors contribute to “noise” in BBS trend analyses including varying degrees of expertise and ageing among observers, as well as weather and random events on breeding, wintering, and stopover sites that may affect birds in one BBS route and not others. We recognize these drawbacks but maintain that trend analyses along single, long-term, BBS routes, when combined with interpretations of overall habitat change along those routes, represents a valuable course of investigation. While conclusions from such analyses must be considered preliminary, this is the nature of scientific investigation, particularly as it relates to pressing conservation issues.

At one time the BBS route at Brightsand, Saskatchewan, had the highest species diversity recorded on any Canadian BBS route, and one of the highest in North America (Johns 1990*). This route, one of few in the forest fringe area of Saskatchewan,

was surveyed consistently for 18 years (1979–1996) by the same observer (Muriel Carlson). The number of species detected per year on the Brightsand route declined sharply between the 1980s and 1990s. Starting in 1990, species richness began to decrease, and by 1995, only 67 bird species were recorded on this route compared to a high of 105 species in 1987. Of those species still recorded on this route, almost all are declining and many of these declines are significant.

In order to determine if species declines were related to local changes in habitat, or were a more widespread phenomenon, we examined other BBS routes surveyed consistently for long periods (i.e., >20 years) both in forest fringe and in continuous forest habitat. Four additional routes with a similar suite of species were added to the analysis; Athabasca, Alberta, surveyed for 26 years by John Kinnaird; Two Hills, Alberta, surveyed for 14 years by Graham Greenle and the last 12 years by David Ealey; Clouston, Saskatchewan surveyed for 23 years by Maurice Mareschal; and Tyndall, Manitoba, surveyed for 26 years (22 by Rudolf Koes). We chose the BBS Bird River, Manitoba, as a control

route. Bird River is the longest running BBS route (surveyed for 21 years by Peter Taylor) located in continuous forest habitat in the Prairie Provinces.

Study Area

Brightsand, Saskatchewan (53° 30' N, 108° 40' W), Clouston, Saskatchewan (53° 06' N, 105° 51' W), Athabasca, Alberta (54° 50' N, 113° 06' W), Two Hills, Alberta (53° 44' N, 111° 32' W), and Tyndall, Manitoba routes (50° 04' N, 96° 36' W), are all located in the Boreal Plain Ecozone (Acton et al. 1998). This ecozone extends across Prairie Canada from southeastern Manitoba to northwestern Alberta and is bounded by the Precambrian Shield to the north and Aspen Parkland to the south (Figure 1). The Boreal Plain Ecozone is a gently rolling plain that was originally covered by boreal mixedwood forest. This forest is composed, of both deciduous [Trembling Aspen (*Populus tremuloides*), Balsam Poplar (*P. balsamifera*), and White Birch (*Betula papyrifera*)] and coniferous [Jack Pine (*Pinus banksiana*), White Spruce (*Picea glauca*), Black Spruce (*P. mariana*) and Balsam Fir (*Abies balsamea*)] (Rowe 1972; Kabzems et al. 1986). The

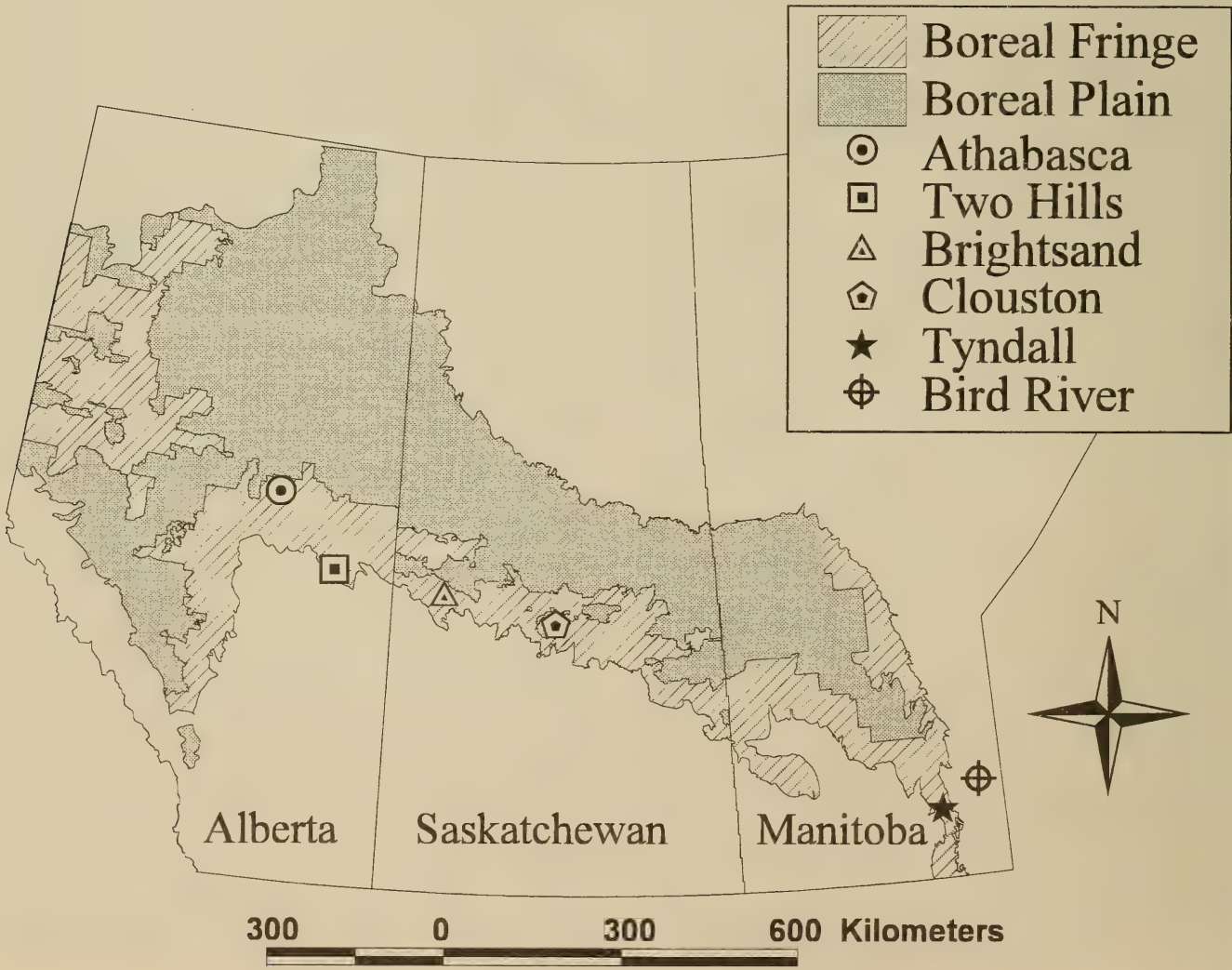


Figure 1. Location of BBS routes in the study.

southern portion of the Boreal Plains is categorised as the Boreal Transition Zone (Kabzems et al. 1986; Acton et al. 1998). This area is an ecotone between the continuous forest of the north and the Aspen Parkland of the south. Like most ecotones, this blending of two different habitats promotes a high species diversity in the area (Smith 1992) and nearly 300 species of birds breed here (Robbins et al. 1986; Acton et al. 1998). However, much of the Boreal Plains, especially the transition zone, has been cleared for agriculture (Kabzems et al. 1986; Acton et al. 1998; Hobson and Van Wilgenburg, unpublished data). In some areas, more than 80% of the forest has been cleared (Acton et al. 1998). Although most of this clearing took place with settlement, 60 or more years ago, in other areas, agriculture continues to expand into the forest, especially in more northern areas.

Our continuous forest site, Bird River, Manitoba (50° 25' N, 95° 42' W) is located in the Boreal Shield Ecozone. This ecozone has similar forest cover to the Boreal Plains, but with more conifer and fewer deciduous trees. Bird species diversity is lower than in the Boreal Plains, but many of the same species occur (Smith 1993).

Methods

We examined North American Breeding Bird Survey (BBS) data for four routes assumed to be affected by loss and fragmentation of local forest habitat: Brightsand, Saskatchewan (1979–1996), Clouston, Saskatchewan (1973–1996, except 1976), Athabasca, Alberta (1972–1996), and Two Hills, Alberta (1971–1996). Tyndall, Manitoba (1971–1996), occurred in a region where local forest cover had increased (R. Koes, personal communication) and Bird River, Manitoba (1976–1996), occurring in continuous forest that had not been impacted by agriculture or forestry were also chosen to determine how changes in land use influenced relative abundance and diversity of bird species. Data for trends of individual bird species and raw data on species numbers were obtained from the BBS WebPage (Sauer et al. 1997*). This source also summarised those species on each route that had declined significantly. We also analysed trends of bird species by guilds. The categories used were; forest, shrubland, grassland, wetland and farm/urban (cosmopolitan) birds. Species were assigned to the different categories using the criteria of the Canadian Breeding Bird Survey (Downes and Collins 1996). Trends in populations by species guilds were analysed by Brian Collins of the Canadian Wildlife Service in Hull, Quebec, using the program BBSANALYS (Collins 1998*). Route trends are estimated using the methods described in Link and Sauer (1994).

In addition to analyses of trends, we examined habitat change along the Brightsand BBS route. We

quantified habitat for the route using two methods. First, the amount of habitat in 1963 was obtained by digitizing the 73F/10 National Topographic Series (NTS) 1:50 000 scale map using Atlas GIS V. 2.0 (ESRI, Redlands California). That coverage was based on photo interpretation from 1963. We obtained Landsat TM satellite imagery from 1994 for the same area, and reclassified 26 cover types to three; forest, water and agriculture/cleared land, to approximate the classifications used in the NTS map-sheet. A georeferenced digital map of Forest Management Agreement areas (FMA) was used to compare loss of forest cover due to agriculture and forestry. Amount of each of the three habitat types was then assessed using the GIS system Idrisi for Windows v. 2.01 (Clark Labs, Clark University, Worcester, Massachusetts). Secondly, in order to more directly link habitat change with bird trends as determined by the BBS, we analysed a buffer area of 400 metres on each side of the BBS route. This distance was chosen because BBS stops are 800 metres apart; therefore, 400 metres on each side of a BBS stop represents the approximate distance over which data for a stop are recorded.

Results

The total numbers of species detected each year on the six BBS routes are shown in Figure 2. Species richness declined at Brightsand (slope = -1.65, $r^2=0.51$, $F=17.55$, $P<0.001$), Clouston (slope = -0.47, $r^2=0.27$, $F=8.1$, $P<0.05$), and Two Hills (slope = -0.92, $r^2=0.55$, $F=29.23$, $P<0.001$) and increased at Tyndall, (slope = +0.42, $r^2=0.44$, $F=18.54$, $P<0.001$). No trends were detected on the Athabasca or Bird River (control) routes. At Brightsand, the average number of species (\pm SD) detected per year was 95.7 ± 2.7 before 1990 but this declined to 74.7 ± 2.2 after 1990 (Mann-Whitney U; $U=4.0$, $Z=-3.13$, $P=0.0017$). Almost every species on this route had a negative population trend, and thirteen species decreased significantly (Table 1). No species was significantly increasing on the Brightsand route. Athabasca and Tyndall each had eight species with significantly negative population trends (Table 1). Only Common Raven significantly increased on the Athabasca route (trend = +19.9, $P=0.04$ $n=24$). Four species showed a significantly increasing population trend on the Tyndall route (Savanna Sparrow, trend = +3.1, $P=0.03$, $n=24$; Chipping Sparrow, trend = +6.2, $P=0.003$, $n=24$; Red-eyed Vireo, trend = +9.6, $P=0.002$, $n=24$; and Yellow Warbler, trend = +4.5, $P=0.03$, $n=24$). Clouston and Two Hills each had four species with significantly negative population trends (Table 1). Neither Clouston or Two Hills had any species with significantly increasing trends, although two species approach significance on the Clouston route (American Robin, trend = +5.3, $P=0.06$, $n=25$; Brown-headed Cowbird, trend = +9.8,

TABLE 1. Species showing significant negative population trends for all routes examined.

Route	Species	Average #/year	Trend	P
Brightsand, Saskatchewan n=18 years (1979-1996)	Blue-winged Teal	6.6	-11.2	**
	Common Snipe	3.1	-10.5	*
	Sora	2.2	-12.4	***
	Veery	1.6	-21.4	***
	Swainson's Thrush	4.6	-9.9	***
	Red-eyed Vireo	63.7	-2.1	*
	Ovenbird	7.1	-9.9	**
	Connecticut Warbler	13.4	-5.0	*
	Clay-coloured Sparrow	51.8	-5.8	**
	Chipping Sparrow	30.1	-11.2	**
	Song Sparrow	38.0	-5.2	**
Athabasca, Alberta n=25 years (1972-1996)	Pied-billed Grebe	1.4	-6.4	***
	Blue-winged Teal	1.9	-5.6	***
	Ruddy Duck	0.2	-8.3	*
	Sora	2.5	-4.4	*
	Common Nighthawk	0.3	-9.8	*
	Red-eyed Vireo	31.0	-1.0	*
	Warbling Vireo	0.2	-14.2	**
	Tennessee Warbler	2.2	-7.1	**
Two Hills, Alberta n=26 years (1971-1996)	Red-necked Grebe	1.8	-7.2	***
	Ruddy Duck	1.1	-9.4	*
	Northern Flicker	2.6	-10.7	***
	Least Flycatcher	22.1	-0.7	**
Clouston, Saskatchewan n=23 years (1973-1996)	American Coot	51.7	-2.0	***
	Northern Flicker	3.9	-2.5	***
	Pied-billed Grebe	3.4	-4.2	*
	American Bittern	5.9	-4.8	***
Tyndall, Manitoba n=26 years (1971-1996)	American Bittern	0.6	-17.7	**
	Blue-winged Teal	0.4	-15.3	*
	Red-headed Woodpecker	0.4	-12.2	**
	Least Flycatcher	11.9	-2.4	***
	Gray Catbird	9.8	-2.0	*
	Veery	0.5	-8.7	**
	Northern Oriole	10.4	-3.4	***

*<.05, **<.01, ***<.001

P=0.07, n=25). On the Bird River route, no species had a significant trend, positive or negative.

To assess whether any particular group of birds was affected more than others, route trend analysis was also done by grouping species into guilds using the program BBSANALYS (Collins 1998*). Species showing significant declines were not restricted to any particular habitat. On the Brightsand BBS route, all guilds showed negative population trends (Table 2). Although forest and wetland birds showed the largest annual declines (-5.0 % and -8.7 %, respectively), grassland and cosmopolitan birds (maggies, crows etc.) also declined. Athabasca showed similar results to Brightsand, except that cosmopolitan birds increased (Table 2). While Two Hills and Clouston were similar to Brightsand and Athabasca in declines of grassland and wetland birds, both routes showed no declines in forest birds and shrubland birds were

relatively stable (Table 2). Guild trends were different on Tyndall than they were on the other four forest fringe routes. Wetland species on Tyndall declined as they had elsewhere, however, forest and cosmopolitan (disturbance-tolerant) species increased, whereas shrubland and grassland birds remained stable.

Forest birds declined on both the Brightsand and Athabasca BBS routes with 10 year annual trends of -40.2% and -18.1%, respectively (Table 2). Even the abundant Red-eyed Vireo (species names given in Appendix A) declined on both these routes (Table 1). Overall, forest birds increased slightly on the Tyndall route but Veery declined. In contrast, on the Bird River route (continuous forest), forest birds increased 12.4% over a 10-year average (Table 2). Species such as Swainson's Thrush, Veery, Ovenbird, and Red-eyed Vireo that were declining on the

Number of Species Detected

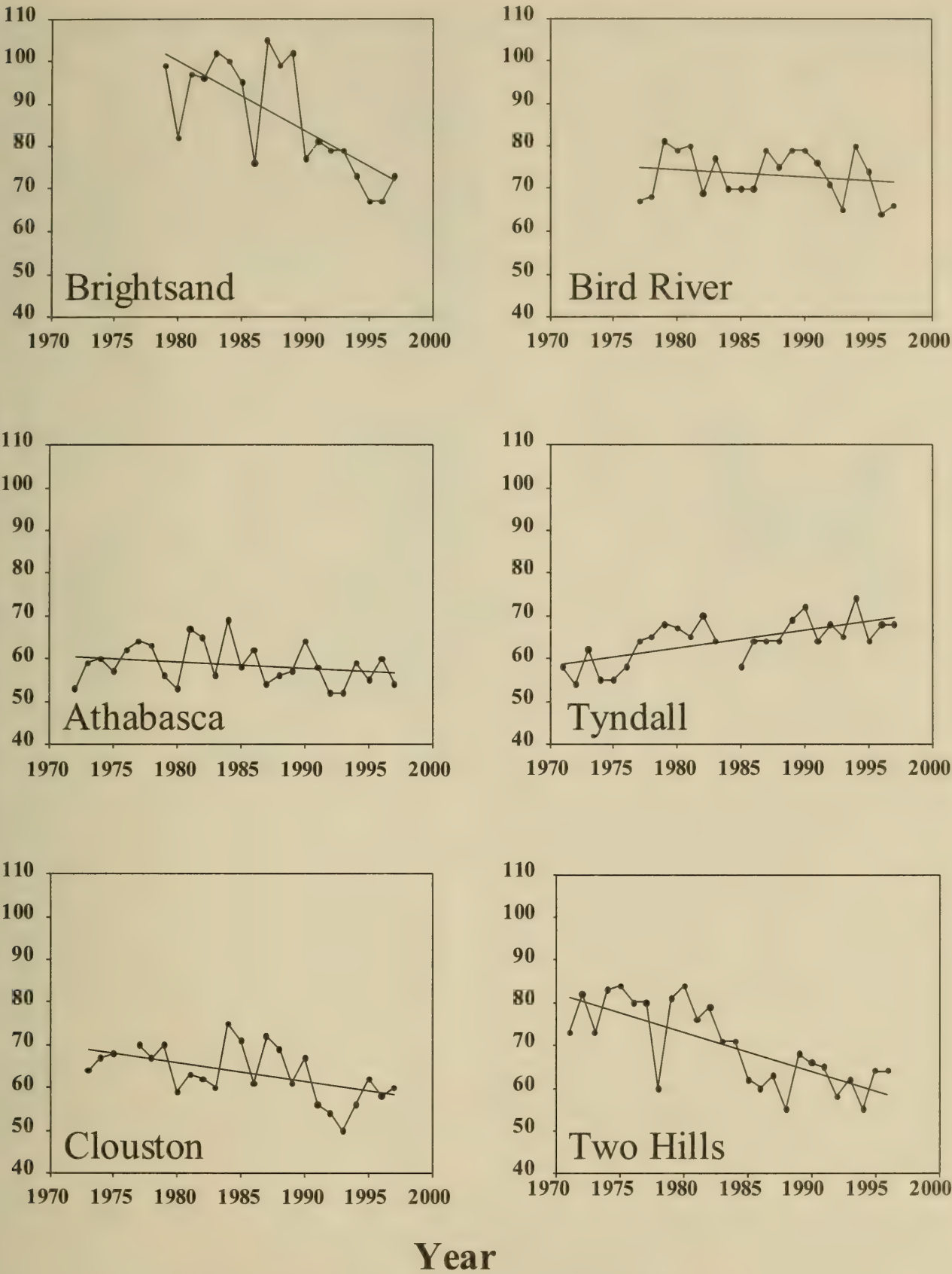


FIGURE 2. Number of species observed each year on BBS routes.

fragmented BBS routes, were either stable or slightly increasing on the Bird River route.

Wetland-associated birds showed the largest decline in all five fragmented BBS routes. Many wetland species such as Pied-billed Grebe, American

Bittern, Blue-winged Teal, Common Snipe and Sora all declined significantly on one or more routes. Blue-winged Teal showed significant declines on three of the BBS routes in the forest transition habitat (Table 1). All five observers (Carlson, Kinnaird,

TABLE 2. Population trends by species guild, in fragmented vs continuous forest habitat for all BBS routes examined. The 10% change refers to an extrapolated ten-year trend based on the regression line for the existing data (B. Collins, personal communication).

Route	Trend	Habitat Guild				
		Forest	Shrubland	Grassland	Wetland	Cosmopolitan
Fragmented						
Brightsand, Saskatchewan	Annual % Change	-5.0	-4.2	-2.9	-8.7	-1.2
	10 year % Change	-40.2	-34.6	-25.6	-59.8	-11.5
Athabasca, Alberta	Annual % Change	-1.9	-4.1	-0.4	-6.8	0.8
	10 year % Change	-18.1	-34.0	-3.9	-50.5	7.9
Two Hills, Alberta	Annual % Change	0.1	0.12	-2.9	-8.5	-2.1
	10 year % Change	1.1	1.20	-25.3	-58.8	-19.0
Clouston, Saskatchewan	Annual % Change	0.8	-0.10	-2.7	-1.9	-0.4
	10 year % Change	8.6	-1.01	-23.8	-17.6	-3.5
Tyndall, Manitoba	Annual % Change	0.7	-0.2	0.1	-3.5	5.9
	10 year % Change	6.8	-2.2	1.2	-29.9	77.6
Continuous						
Bird River, Manitoba	Annual % Change	1.2	1.5	n/a	3.1	-0.2
	10 year % Change	12.4	16.4	n/a	36.2	-1.9

Mareschal, Ealey and Koes), informed us that many of the marshes and small ponds along their BBS routes had been drained and broken for crops. Only at Bird River, the contiguous forest site, did all guilds remain stable or increase. This was the only BBS route examined where wetland birds increased.

By contrasting landscape changes along the Brightsand BBS route with changes occurring within the larger Landsat mapsheet (inside and outside of the FMA) we were able to examine to what extent our BBS analysis was typical of a much larger area. A significant amount of habitat change occurred along the Brightsand BBS route between 1963 and 1994 (Table 3). Of forest cover within the 400 metre buffer in 1963, only 48.2% remained in 1994. Similarly, only 54.7% of forest outside of FMAs remained in 1994 when the entire mapsheet was examined (Figure 3). Within the BBS buffered area, 87.2% of the water remained in 1994, whereas 96.1% remained of all waterbodies outside of the FMA over the entire mapsheet. For waterbodies inside the FMA however, 84.9% remained in 1994. Amount of land under cultivation increased by

85.6% over the same time period within the 400 metre buffer, and by 117.6% for the entire mapsheet.

Discussion

The number of species recorded along the Brightsand BBS route has decreased significantly since the 1980s and many of the species remaining have declined significantly in relative abundance. The most likely reasons for these declines are a combination of forest and wetland habitat loss and fragmentation. Our GIS analyses showed that along the Brightsand BBS route in the past 31 years, 51.8% of the forest and 12.8% of the wetlands have been lost. In addition, many of the pastures in this area have been broken for crops (Muriel Carlson, personal communication). This may explain declines in abundance of forest, grassland and wetland species.

Similar patterns of species declines were also detected on the Athabasca, Two Hills, and Clouston BBS routes. Coinciding with the opening of the Alpac Mill in 1993, many farm woodlots were cleared and much of the forest habitat disappeared from this area (John Kinnaird, personal communica-

TABLE 3. Habitat change for the Brightsand BBS route and mapsheet, determined from a digitized NTS map (1963) and Landsat TM satellite imagery (1994). FMA refers to Forest Management Area.

	Within 400 meters of BBS route				Entire Mapsheet			
	1963 (Ha)	1994 (Ha)	Change (%)	Change/year (%)	1963 (Ha)	1994 (Ha)	Change (%)	Change/year (%)
Water	79.8	69.6	-12.8	-2.81	11629.3	11180.6	-3.9	-3.10
Forest	1905.6	919.2	-51.8	-1.56	43845.0	23973.3	-45.3	-1.76
Agriculture/Cleared Land	1163.7	2160.3	85.6	5.99	17280.5	37600.9	117.6	7.02
Water inside FMA	—	—	—	—	1349.6	1145.9	-15.1	-2.74
Forest Cover in FMA	—	—	—	—	17770.0	17973.8	1.1	3.26

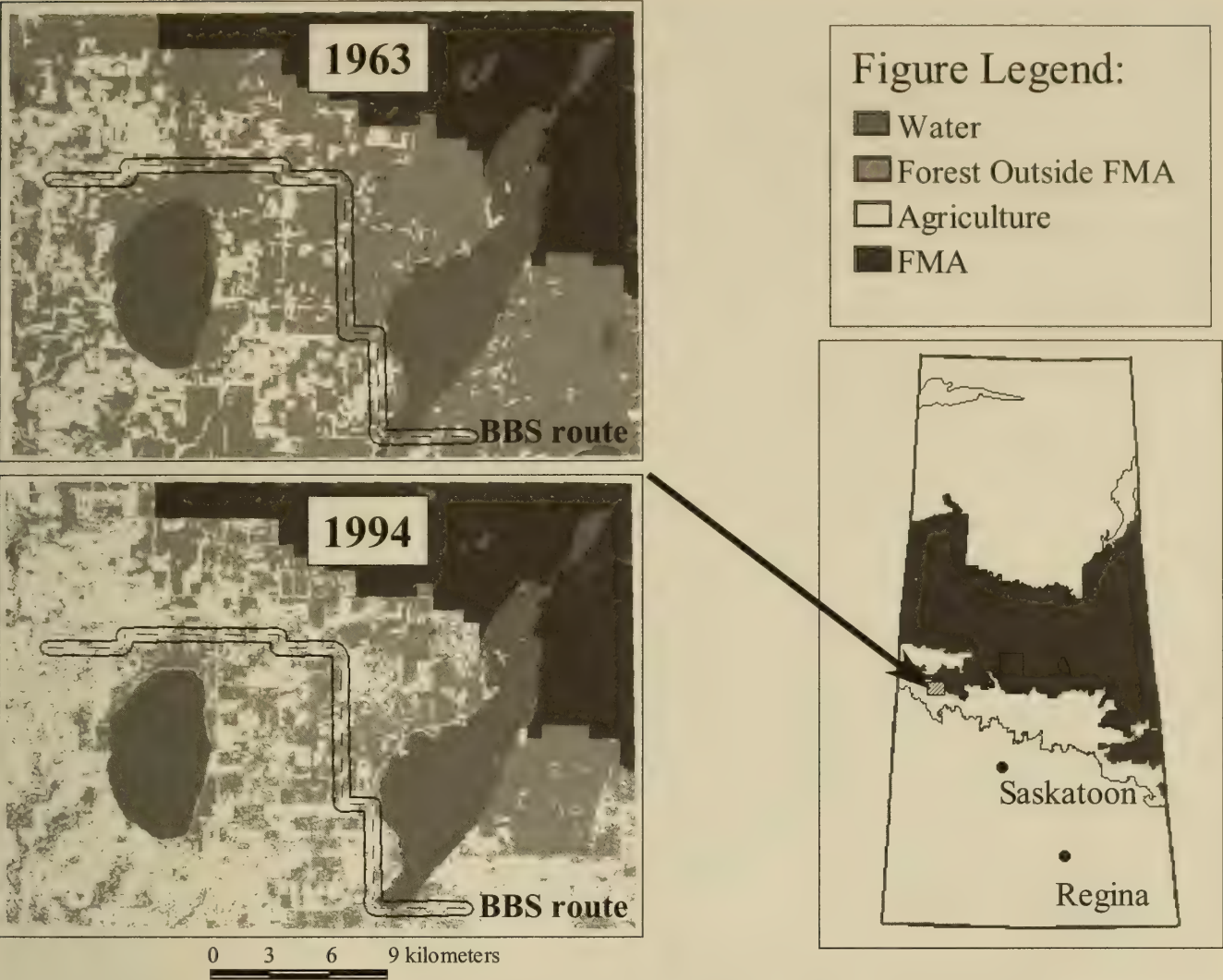


FIGURE 3. The Brightsand BBS route and the buffered area analysed from digital coverage for 1963 (NTS) and 1994 (Landsat TM). FMA refers to Forest Management Area.

tion). On the Two Hills route, dramatic changes in species richness and abundance occurred since 1985. This involved a period of road straightening and widening corresponding with the removal of trees and shrubs along roadways. A major tent caterpillar infestation took place in the late 1980s which was followed by extensive clearing of aspen forest. A period of dry years in the late 1980s resulted in many wetlands being cleared for agriculture. During the past five years, farmers have taken advantage of private timber sales to the Alpac mill and this has resulted in loss of woodlots, especially mixedwoods. Finally, a recent increase in livestock production, including elk ranching, has resulted in intensive land use that has impacted bird habitat (David Ealey, personal communication). On the Tyndall BBS route, most of the forest clearing took place 60 or more years ago. Some of the farms in the area have since been abandoned and patches of young aspen are starting to mature (Rudolf Koes, personal communication). This may explain why overall species diversity increased on this route.

On the Brightsand route, several species occurring

in the 1980s disappeared in the 1990s. Many of these declines were not statistically significant due to low statistical power since most of these species occurred in low numbers. From a biological perspective, however, it is worth noting that species which formerly bred in this area have since disappeared. In 1982, the Brightsand BBS route had the second highest number (n=25) of Connecticut Warblers recorded for any BBS route in North America (Price et al. 1995), by 1995, only five were recorded. Ovenbird declined from 20 in 1979 to 2 by 1996, and Veery declined from 10 in 1979 to zero by 1992.

Roadside habitat loss along the Brightsand BBS survey route is representative of landscape change at a much larger scale. For example, in the area south of Prince Albert National Park, an area also in the forest transition zone, estimates using Landsat satellite images have shown that the rate of deforestation in the last 20 years has been approximately 1.3% per year (Hobson and Van Wilgenburg, unpublished data; Environment Canada 1991*; Fitzsimmons et al. 1997*; Alberta Environmental Protection 1998*). The rate of deforestation found in this and the above

mentioned studies far exceed the world average of 0.3% per year and come close to the highest rates in the world (FAO 1999*). Remaining forest patches, are becoming more fragmented and isolated. Birds requiring forest interiors for breeding do not occur in small woodlots, and other species that breed in these woodlots may find them to be "ecological sinks" (Pulliam 1988; Robbins et al. 1989; Donovan et al. 1995; Hobson and Bayne 2000). Birds nesting in isolated forest fragments can suffer from higher rates of nest depredation and nest parasitism reducing their reproductive success (Wilcove 1985; Wilcove and Robinson 1990; Robinson et al. 1995).

Some species declines may be exacerbated by habitat degradation in the Neotropics (Askins et al. 1990; Rappole and McDonald 1994; Sherry and Holmes 1996), however, many of the species which have declined or disappeared on the BBS routes are not restricted to this group. (e.g., American Bittern, Common Snipe, and Northern Flicker). Neotropical migrants such as Veery, Swainson's Thrush and Ovenbird, declined in the forest transition areas, but were stable on the continuous forest Bird River BBS route. This strongly suggests an influence of breeding habitat change at the BBS route level. Kirk et al. (1997) in their comparison of surveys conducted at forested sites in boreal Manitoba and Saskatchewan between the 1970s and 1990s also present evidence for changes in breeding habitat as causing population declines of Neotropical migrants.

Canadian BBS records from 1966 to 1994 show that in the Boreal Plains ecoregion, 15 species had a significant negative population trend; Pied-billed Grebe, Northern Pintail, Ruddy Duck, Northern Harrier, Killdeer, Lesser Yellowlegs, Franklin's Gull, Black-billed Cuckoo, Short-eared Owl, Horned Lark, Veery, Chipping Sparrow, Clay-coloured Sparrow, Song Sparrow and Bobolink (Downes and Collins 1996). Many of these were the same species that also declined or have disappeared from Brightsand and the other BBS routes we examined in the forest fringe portion of this ecoregion. Similarly, American Bittern, Common Snipe, Sora, Black Tern, and Veery, species showing declines across North America (1966–1993, Price et al. 1995), also declined or disappeared at Brightsand, but not on our Bird River control route.

We recognize that our control route was inadequate for all species recorded along those routes subject to habitat loss (i.e. our "experimental" routes). Ideally, the use of control routes that closely matched habitat characteristics at the beginning of the sampling period for all experimental routes would have been more useful but such a paired design was impossible in our region. Our control route was located in a different ecoregion than the experimental routes but the forest and wetland bird communities were similar. Thus, at the level of

species by species comparisons, we feel that the control area was valid.

Habitat alteration and fragmentation in the southern boreal forest transition zone is a serious conservation problem that has largely been overlooked by the scientific and conservation community. Expansion of agriculture, clearing of forest, and draining of wetlands is undoubtedly contributing to the decline of many avian species. For example, in the Aspen Parkland and southern boreal mixedwoods of Saskatchewan, many forest interior species did not occur in small, isolated woodlots (Johns 1993; Hobson and Bayne 2000). We can expect declines in these species as forest is removed and fragmented. Similarly, intensification of agriculture also results in wetland loss and alteration as well as the loss of meadows and parkland with clear impacts on birds associated with these habitats. We have shown that such habitat alterations correspond well with BBS data from this area. We encourage similar examination of other BBS datasets, particularly at the regional level where habitat alterations can be quantified.

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APPENDIX A. All birds recorded on the Brightsand BBS route (141 species). Species in bold are those which disappeared in the 1990s.

Non-Passerines		Passerines	
Common Name	Scientific Name	Common Name	Scientific Name
Common Loon	<i>Gavia immer</i>	Olive-sided Flycatcher	<i>Contropus borealis</i>
Pied-billed Grebe	<i>Podilymbus podiceps</i>	Western Wood-Pewee	<i>Contropus sordidulus</i>
Western Grebe	<i>Achmophorus occidentalis</i>	Alder Flycatcher	<i>Empidonax alnorum</i>
Eared Grebe	<i>Podiceps nigricollis</i>	Least Flycatcher	<i>Empidonax minimus</i>
Horned Grebe	<i>Podiceps auritus</i>	Eastern Phoebe	<i>Sayornis phoebe</i>
Red-necked Grebe	<i>Podiceps grisengena</i>	Say's Phoebe	<i>Sayornis saya</i>
American White Pelican	<i>Pelecanus erythrorhynchos</i>	Great-crested Flycatcher	<i>Myarchus crinitus</i>
Double-crested Cormorant	<i>Phalacrocorax auritus</i>	Eastern Kingbird	<i>Tyrannus tyrannus</i>
American Bittern	<i>Botaurus lentiginosus</i>	Horned Lark	<i>Eremophila alpestris</i>
Great-blue Heron	<i>Ardea herodias</i>	Purple Martin	<i>Progne subis</i>
Black-crowned Night-Heron	<i>Nycticorax nycticorax</i>	Tree Swallow	<i>Tachycineta bicolor</i>
Sandhill Crane	<i>Grus canadensis</i>	Bank Swallow	<i>Ripara ripara</i>
Canada Goose	<i>Branta canadensis</i>	Barn Swallow	<i>Hirundo rustica</i>

Continued

APPENDIX A. (Continued).

Non-Passerines		Passerines	
Common Name	Scientific Name	Common Name	Scientific Name
Green-winged Teal	<i>Anas crecca</i>	Gray Jay	<i>Perisoreus canadensis</i>
Mallard	<i>Anas platyrhynchos</i>	Blue Jay	<i>Cyanocitta cristata</i>
Northern Pintail	<i>Anas acuta</i>	Black-billed Magpie	<i>Pica pica</i>
Blue-winged Teal	<i>Anas discors</i>	American Crow	<i>Corvus brachyrhynchos</i>
Notern Shoveler	<i>Anas clypeata</i>	Common Raven	<i>Corvus corax</i>
Gadwall	<i>Anas strepera</i>	Black-capped Chickadee	<i>Parus atricapillus</i>
American Widgeon	<i>Anas americana</i>	Boreal Chickadee	<i>Parus hudsonicus</i>
Canvasback	<i>Aythya valisineria</i>	Red-breasted Nuthatch	<i>Sitta canadensis</i>
Redhead	<i>Aythya ferina</i>	House Wren	<i>Troglodytes aedon</i>
Ring-necked Duck	<i>Athya collaris</i>	Marsh Wren	<i>Cistothorus palustris</i>
Lesser Scaup	<i>Aythya affinis</i>	Ruby-crowned Kinglet	<i>Regulus satrapa</i>
White-winged Scoter	<i>Melanitta perspicillata</i>	Mountain Bluebird	<i>Sialia currucoides</i>
Common Goldeneye	<i>Bucephala clangula</i>	Veery	<i>Catharus fuscescens</i>
Bufflehead	<i>Bucephala albeola</i>	Swainson's Thrush	<i>Catharus ustulatus</i>
Red-breasted Merganser	<i>Mergus serrator</i>	Hermit Thrush	<i>Catharus guttatus</i>
Ruddy Duck	<i>Oxyura jamaicensis</i>	American Robin	<i>Turdus migratorius</i>
Yellow Rail	<i>Coturnicops noveboracensis</i>	Gray Catbird	<i>Dumetella carolinensis</i>
Sora	<i>Porzana carolina</i>	Brown Thrasher	<i>Toxostoma rufum</i>
American Coot	<i>Fulica americana</i>	Sprague's Pipit	<i>Anthus spragueii</i>
American Avocet	<i>Recurvirostra americana</i>	Cedar Waxwing	<i>Bombycilla cedrorum</i>
Killdeer	<i>Charadrius vociferus</i>	European Starling	<i>Sturna vulgaris</i>
Willet	<i>Catoptrophorus semipalmatus</i>	Solitary Vireo	<i>Vireo solitarius</i>
Spotted Sandpiper	<i>Actitis macularia</i>	Warbling Vireo	<i>Vireo gilvus</i>
Common Snipe	<i>Gallinago gallinago</i>	Philadelphia Vireo	<i>Vireo philadelphicus</i>
Franklin's Gull	<i>Larus pipixcan</i>	Red-eyed Vireo	<i>Vireo olivaceus</i>
Bonaparte's Gull	<i>Larus philadelphia</i>	Tennessee Warbler	<i>Vermivora peregrina</i>
Ring-billed Gull	<i>Larus delawarensis</i>	Orange-crowned Warbler	<i>Vermivora celata</i>
Herring Gull	<i>Larus argentatus</i>	Yellow Warbler	<i>Dendroica petechia</i>
California Gull	<i>Larus californicus</i>	Chestnut-sided Warbler	<i>Dendroica pensylvanica</i>
Common Tern	<i>Sterna hirundo</i>	Magnolia Warbler	<i>Dendroica magnolia</i>
Black Tern	<i>Chlidonias niger</i>	Yellow-rumped Warbler	<i>Dendroica cornata</i>
Northern Harrier	<i>Circus cyaneus</i>	Palm Warbler	<i>Dendroica palmarum</i>
Red-tailed Hawk	<i>Buteo jamaicensis</i>	Black-and-White Warbler	<i>Minotilta varia</i>
American Kestrel	<i>Falco sparverius</i>	American Redstart	<i>Setophaga ruticilla</i>
Merlin	<i>Falco columarius</i>	Ovenbird	<i>Seiurus aurocapillus</i>
Ruffed Grouse	<i>Bonasa umbellus</i>	Northern Waterthrush	<i>Seiurus noveboracensis</i>
Sharp-tailed Grouse	<i>Tympanuchus pallidicinctus</i>	Connecticut Warbler	<i>Oporornis agilis</i>
Gray Partridge	<i>Perdix perdix</i>	Mourning Warbler	<i>Oporornis philadelphia</i>
Mourning Dove	<i>Zenaidura macroura</i>	Common Yellowthroat	<i>Geothlysis trichas</i>
Black-billed Cuckoo	<i>Coccyzus erythrophthalmus</i>	Rose-breasted Grosbeak	<i>Pheucticus ludovicianus</i>
Great-horned Owl	<i>Bubo virginianus</i>	Spotted Towhee	<i>Pipilo erythrophthalmus</i>
Common Nighthawk	<i>Chordeiles minor</i>	Chipping Sparrow	<i>Spizella passerina</i>
Ruby-throated Hummingbird	<i>Archilochus colubris</i>	Clay-coloured Sparrow	<i>Spizella pallida</i>
Belted Kingfisher	<i>Ceryle alcyon</i>	Vesper Sparrow	<i>Pooecetes gramineus</i>
Yellow-bellied Sapsucker	<i>Sphyrapicus varius</i>	Savanna Sparrow	<i>Passerculus sandwichensis</i>
Downy Woodpecker	<i>Picoides pubescens</i>	LeConte's Sparrow	<i>Ammodramus lecontei</i>
Hairy Woodpecker	<i>Picoides villosus</i>	Sharp-tailed Sparrow	<i>Ammodramus caudacutus</i>
Pileated Woodpecker	<i>Dryocopus pileatus</i>	Song Sparrow	<i>Melospiza melodia</i>
Northern Flicker	<i>Colaptes auratus</i>	Lincoln's Sparrow	<i>Melospiza lincolni</i>
		Swamp Sparrow	<i>Melospiza georgiana</i>
		White-throated Sparrow	<i>Zonotrichia albicollis</i>
		Dark-eyed Junco	<i>Junco hyemalis</i>
		Bobolink	<i>Dolichonyx oryzivorus</i>
		Red-winged Blackbird	<i>Agelaius phoeniceus</i>
		Western Meadowlark	<i>Sturnella neglecta</i>
		Yellow-headed Blackbird	<i>Xanthocephalus xanthocephalus</i>

Continued

APPENDIX A. (Concluded).

Non-Passerines		Passerines	
Common Name	Scientific Name	Common Name	Scientific Name
		Rusty Blackbird	<i>Euphagus carolinus</i>
		Brewer's Blackbird	<i>Euphagus cyanocephalus</i>
		Common Grackle	<i>Quiscalus quiscula</i>
		Brown-headed Cowbird	<i>Molothrus ater</i>
		Northern Oriole	<i>Icterus galbula</i>
		Purple Finch	<i>Carpodacus purpureus</i>
		Pine Siskin	<i>Carduelis pinus</i>
		American Goldfinch	<i>Carduelis tristis</i>
		Evening Grosbeak	<i>Coccothrausters vespertinus</i>
		House Sparrow	<i>Passer domesticus</i>

The Spring and Fall Migrations of Scoters, *Melanitta* spp., at Confederation Bridge in the Northumberland Strait between New Brunswick and Prince Edward Island

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With assistance from volunteer observers on both sides of the Confederation Bridge, we counted and identified the three species of scoters migrating through the Northumberland Strait between New Brunswick and Prince Edward Island in spring and fall in order to assess whether the presence of Confederation Bridge affected the migration of scoters through the Strait. The numbers of scoters using Northumberland Strait during migration were three times greater in spring than fall. In both spring and fall, Surf Scoters were the most abundant species followed by Black and White-winged scoters. Only 13% of the scoters flew across Confederation Bridge in spring, and 22% in the fall. It is assumed that the remainder of the birds flew either (1) around Prince Edward Island in order to reach the Gulf of St. Lawrence in spring and the Strait of Canso in the fall or (2) high above Confederation Bridge and were not seen by the observers.

Key Words: Black Scoter, Surf Scoter, White-winged Scoter, seaducks, migration, Northumberland Strait, Confederation Bridge, Cape Jourimain, New Brunswick, Borden, Prince Edward Island.

Confederation Bridge, spanning 13 kilometers across Northumberland Strait between New Brunswick and Prince Edward Island (Figure 1), was begun in 1995 and completed in spring 1997. In 1990, the Canadian Wildlife Service (CWS) conducted surveys of seaducks and other seabirds in Northumberland Strait from Cape Jourimain National Wildlife Area (MacKinnon et al. 1991). The present study (conducted from the same observation site) was initiated in 1997, immediately following completion of construction, to determine if the presence of the bridge affected migration of scoters through the Northumberland Strait during the birds' spring and fall migrations.

Materials and Methods

Observation Sites

In 1990, seaduck observations were conducted from Money Point (46°09'N, 63°49'W) on Jourimain Island on the New Brunswick side of Northumberland Strait (see MacKinnon et al. 1991). In spring 1997, a single observer conducted surveys from Money Point. During the fall, two observers conducted the observations, one at each end of the bridge: Money Point at Cape Jourimain, New Brunswick, and Borden Point in Borden, Prince Edward Island (see Figure 2).

A. Cape Jourimain, New Brunswick

Principally a farming area, Cape Jourimain may have been settled as early as 1720. In 1933, Jourimain Island and Trenholme island were appropriated by the province of New Brunswick. By that time, the

Jourimain area consisted of six farmsteads: two on the mainland and the two on each island, owned by members of the Allen and Trenholme families since 1810 (Harries 1996). The road now leading to Confederation Bridge (including causeways between the two islands) was built in 1965 prior to its designation as a National Wildlife Area by the CWS in 1979.

Except for observations conducted during early morning, the sun was usually behind the observers in 1997 thus allowing a clear view of the birds. All species seen from this observation site were recorded. A total of 49.8 person-hours of observations were conducted at Cape Jourimain in spring from 14 April to 1 May, inclusive, and similar surveys were undertaken from the same site over 156 person-hours during the fall migration between 18 September and 18 November, inclusive.

Volunteers used 7 × 35 mm and 10 × 42 mm binoculars and a Bausch & Lomb 15-60× telescope. The start and end times of observations were noted so that the rates at which species crossed the bridge (number of birds/hr) could be computed.

B. Borden, Prince Edward Island

The town of Borden was the former Prince Edward Island docking site of the Northumberland ferries (Figure 2). Observations from Prince Edward Island were carried out only during fall (nine days in October and nine days in November) for a total of 41.9 person-hours of observations. No surveys were undertaken from Prince Edward Island in 1990 (MacKinnon et al. 1991). An observer was placed at Borden Point in 1997 after a substantial number of seaducks first



FIGURE 1. The Confederation Bridge across the Northumberland Strait between New Brunswick and Prince Edward Island.

sighted from New Brunswick were seen to fly parallel to the bridge towards Prince Edward Island until they were lost from view and before they could be accurately identified. Thus, an observer on the Prince Edward Island side was necessary to count and identify all the birds that reached visible range from the island. This observer was located under the bridge at Borden, looking towards New Brunswick to document only the numbers and species of seaducks, primarily scoters, reaching and crossing the bridge.

Results

1. Spring

Forty-one species of birds were seen from Cape Jourimain at Confederation Bridge in spring (Table 1). As this project was primarily concerned with scoters, only the observations of Black Scoters *Melanitta nigra*, Surf Scoters *M. perspicillata* and White-winged Scoters *M. fusca* are presented here. The numbers of scoters seen in the spring, and their rates of movement are shown in Table 2.

The northward migration of scoters was already in progress when the observations began on 14 April, when 209 scoters were recorded (Table 2). The largest flocks of scoters seen in spring consisted of 1200 Surf Scoters and 320 Black Scoters resting on the water, south of the bridge, on 17 April. The first White-winged Scoter (1 bird) was seen on 26 April and scoter numbers peaked the following day (150 birds) with the last 16 White-wings observed on 1 May, the final day of observations (Table 2).

In the spring, a relatively low proportion of the scoters which reached the bridge actually crossed it. Many landed in nearby waters or continued flying

along the bridge towards Prince Edward Island. On a daily basis, birds which were seen flying over Confederation Bridge ranged between 3.6%–100% of the totals which had migrated into the area. Overall, out of a total of 3986 scoters observed at the bridge in spring, 1997, 12.8% were seen to cross over the bridge (Table 3).

2. Fall

From the New Brunswick side, 47 species of birds were seen during fall observations between 18 September and 18 November 1997 (see Table 1). The numbers of scoters seen from Cape Jourimain are shown in Table 4. The proportions of those birds which were seen to cross Confederation Bridge are presented in Table 5 and the numbers of scoters observed at Borden are shown in Table 6.

Observations began in New Brunswick on 18 September when 20 Surf Scoters and 7 White-winged Scoters were first observed flying towards the bridge (Table 4). They sharply veered away from the bridge and appeared to be disturbed by the presence of the structure. Clearly, the southward migration of scoters was already well underway by mid-September. In 1990, small numbers of Black and Surf scoters were seen on 7 September, the first of fall observations in that year (MacKinnon et al. 1991). In 1997, between 6 and 18 October, the largest flocks seen throughout the 28-day observation period at Cape Jourimain totalled 689 scoters (identified and unidentified). These included 220 Surf Scoters (31.9%), 74 Black Scoters (10.7%), 71 White-winged Scoters (10.3%) and 324 (47.1%) unidentified scoters (see Table 4).

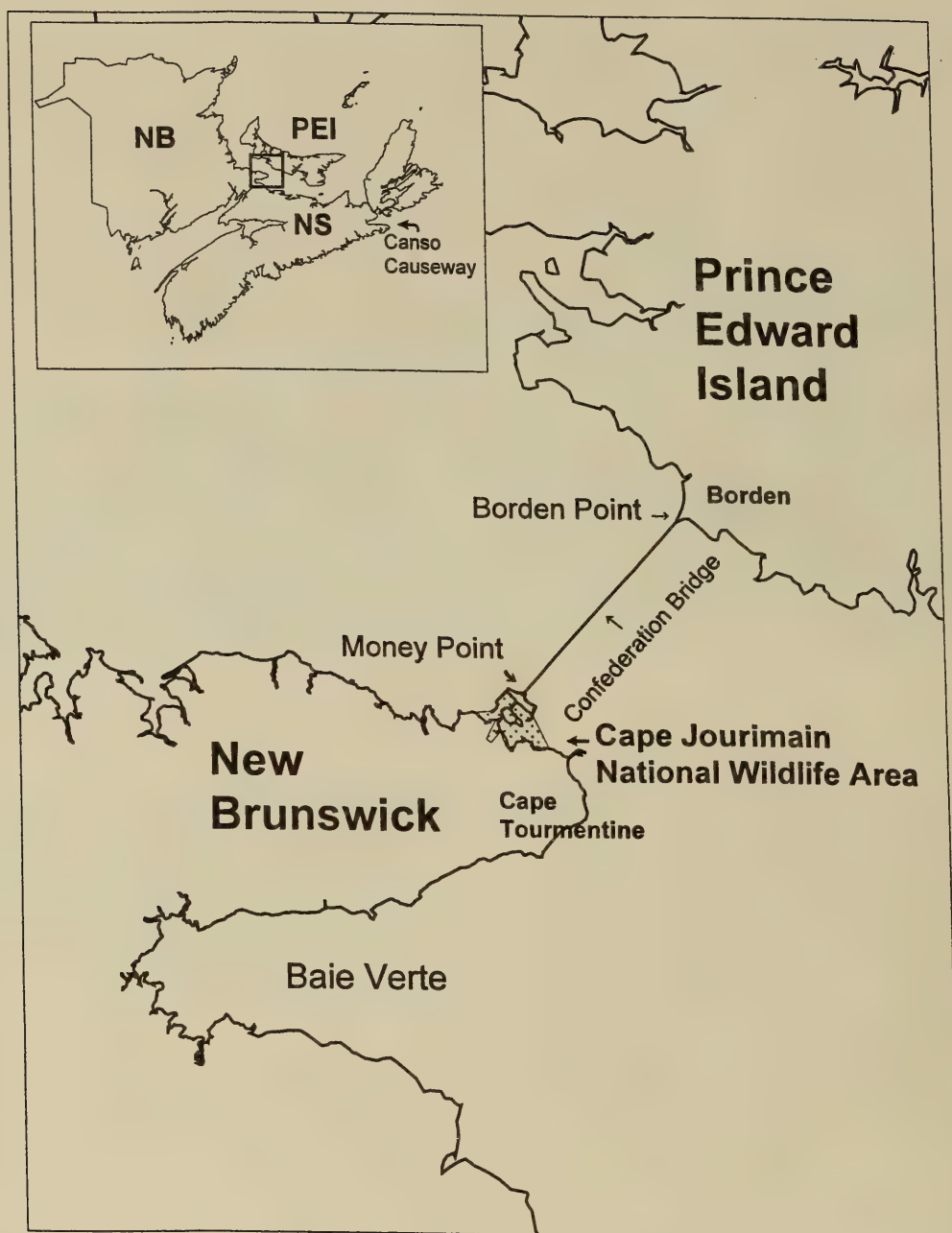


FIGURE 2. Location of the Confederation Bridge between New Brunswick and Prince Edward Island.

The observations from the New Brunswick side showed that not all the scoters flew across the bridge once they reached it: on 14 of the 28 days when scoters were seen from New Brunswick (50% of the observations), birds were seen to fly over the bridge (see Table 5). Of the total numbers seen reaching the bridge on those days, between 4.5% and 66.1% of the birds recorded actually crossed over Confederation Bridge (Table 5). Overall, only 22% of all scoters seen from New Brunswick during autumn, flew over Confederation Bridge. The remainder either turned away from the bridge or flew high, parallel to it towards Prince Edward Island, until they were lost from view by the New Brunswick observer. On the Prince Edward Island

side, once scoters were seen, they were observed to fly over the bridge. However, we were unable to determine whether the two observers actually watched the same birds or if some of those birds flying high from New Brunswick were ever seen on the Prince Edward Island side because of the great heights they reached.

From the Prince Edward Island side, observations were not begun until late in the migration period when maximum numbers were already being recorded in New Brunswick. From 17 October to 18 November, a total of 814 scoters were seen from Cape Jourimain (see Table 5). At Borden, from 17 October to 26 November, 475 birds (58.4% of the New Brunswick total) were sighted (Table 6).

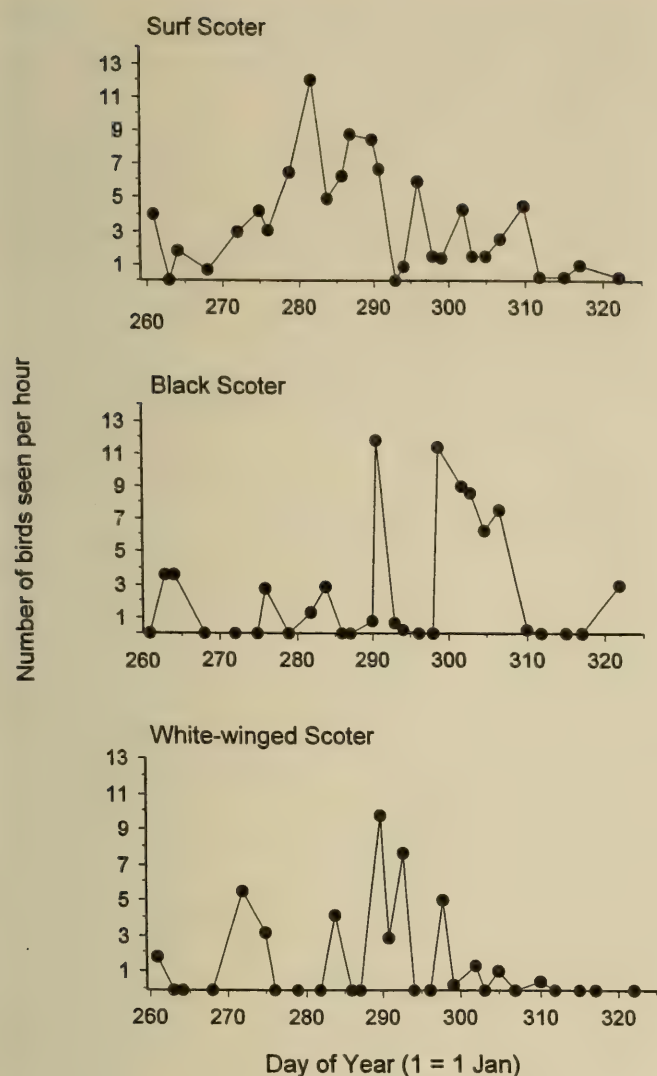


FIGURE 3. The numbers of scoters seen at Confederation Bridge from Cape Jourimain, New Brunswick, 17 September (day 260) to 20 November (day 322) 1997.

In New Brunswick, all three species were first encountered on 18–20 September and Surf and Black scoters were still present on the last day of observation (18 November); the last White-winged Scoters (2) were seen on 6 November (Table 4). Of the total numbers of scoters seen over the 28 days of observations at Cape Jourimain, the percentages of the three species seen were 26.8% Surfs, 20.1% Blacks, 11.1% White-winged while 41.9% remained unidentified.

The rates of movement (number of scoters seen per hour) on the New Brunswick side of the Strait ranged from a peak of 37.1/hr on 11 October to 1.3/hr on 13 November (Table 4). From Borden, the rates of movement ranged from 44.6/hr on 20 October to 1.0/hr on 3 and 4 November (Table 6).

Based on the daily total numbers of birds seen at Cape Jourimain, the migration of scoters through the Northumberland Strait peaked in early to mid-October, between 6 and 20 October (Table 4). Peaks

of White-winged Scoters remain unclear, possibly 17–25 October, and Black Scoters peaked later, around 26 October to 3 November (Table 4). Hence, based on those birds identified by the observers, Surf Scoters reached Confederation Bridge in early October, White-winged Scoters in mid-October and Black Scoters in late October-early November (Figure 3). On the Prince Edward Island side, the largest numbers of scoters were seen on 22–28 October, slightly later than when peak numbers were recorded in New Brunswick, although most could not be identified to species (see Table 6).

Of all three species of scoters which were identified from Cape Jourimain in October and November, Surf Scoters were clearly the predominant species using the Northumberland Strait during the fall migration. Of these (836), 46.2% were Surf, 34.7% Black, and 19.1% White-winged scoters (see Table 4).

Of the 1441 scoters observed in the fall from Cape Jourimain, only 316 (21.9%), flew across the bridge (Table 5). This proportion varied daily between 4.5% and 66.1% (Table 5).

Discussion

The numbers of scoters seen using Northumberland Strait during northward migration were nearly three times greater than those in fall (3986 vs. 1441, respectively; see Tables 2 and 4). That the bridge proved to be a “barrier” to scoters migrating through the Northumberland Strait is suggested by the low proportions seen to fly over the bridge (12.8% in spring, 21.9% in fall). However, as the total numbers seen migrating through the area in daytime were relatively low (<5000 birds), the bridge cannot be considered a major impediment to the migration of the eastern breeding North American populations of Surf and Black scoters which number over 62 000 pairs (see Bordage and Savard 1995; Savard et al. 1998). We speculate that some birds which do not fly over Confederation Bridge detour around Prince Edward Island to reach the Strait of Canso where other seabirds (Common Eiders *Somateria mollissima*) have been seen to cross high over the Canso causeway (A. J. Erskine, personal communication; see Figure 1). Birds which leave the New Brunswick coast and fly high towards Prince Edward Island along the bridge may similarly cross high over land once they reach the island.

The 475 scoters seen on the Prince Edward Island side between 17 October and 26 November (Table 6) represent only 37% of the numbers counted on the New Brunswick side (1320) on the same dates. Furthermore, the numbers seen from Prince Edward Island do not correspond closely with the numbers seen on the New Brunswick side on the same days (see Tables 4 and 6). Therefore, these observations suggest that the remaining 54.5% either (1) crossed high overland at Borden, Prince Edward Island, and

TABLE 1. The species of birds seen in spring (•) and fall (◊) off Cape Jourimain, New Brunswick, in spring (14 April and 1 May, inclusive) and fall (18 September and 18 November, inclusive) 1997.

GAVIFORMES

Gaviidae

- Common Loon *Gavia immer* ◊
Red-throated Loon, *Gavia stellata* •◊

PODICIPEDIFORMES

Podicipedidae

- Horned Grebe *Podiceps auritus* ◊
Red-necked Grebe *Podiceps grisegena* ◊

PROCELLARIIFORMES

Procellariidae

- Leach's Storm Petrel *Oceanodroma leucorhoa* ◊

PELECANIFORMES

Sulidae

- Northern Gannet *Sula bassanus* •◊

Phalacrocoracidae

- Double-crested Cormorant *Phalacrocorax auritus* •◊
Great Cormorant *Phalacrocorax carbo* •

CICONIIFORMES

Ardeidae

- Great Blue Heron *Ardea herodias* •◊

ANSERIFORMES

Anatidae

- Canada Goose *Branta canadensis* •◊
American Black Duck *Anas rubripes* •◊
Northern Pintail *Anas acuta* ◊
Scaup *Aythya* spp. •
Common Eider *Somateria mollissima* •◊
Harlequin Duck *Histrionicus histrionicus* •
Oldsquaw *Clangula hyemalis* •◊
Black Scoter *Melanitta nigra* •◊
Surf Scoter *Melanitta perspicillata* •◊
White-winged Scoter *Melanitta fusca* •◊
Common Goldeneye *Bucephala clangula* •
Common Merganser *Mergus merganser* •◊
Red-breasted Merganser *Mergus serrator* •◊

FALCONIFORMES

Accipitridae

- Osprey *Pandion haliaetus* •◊
Bald Eagle *Haliaeetus leucocephalus* •◊
Northern Harrier *Circus cyaneus* •◊
Sharp-shinned Hawk *Accipiter striatus* •◊

Falconidae

- American Kestrel *Falco sparverius* •
Merlin *Falco columbarius* •

GALLIFORMES

Phasianidae

- Grouse spp. ◊

CHARADRIIFORMES

Scolopacidae

- Spotted Sandpiper *Actitis macularia* ◊
Sanderling *Calidris alba* ◊

Laridae

- Bonaparte's Gull *Larus philadelphia* ◊
Iceland Gull *Larus glaucoides* •◊
Greater Black-backed Gull *Larus marinus* •◊
Herring Gull *Larus argentatus* •◊
Caspian Tern *Sterna caspia* ◊
Common Tern *Sterna hirundo* ◊

STRIGIFORMES

Strigidae

- Great Horned Owl *Bubo virginianus* •
Short-eared Owl *Asia flammeus* •

CORACIIFORMES

Alcedinidae

- Belted Kingfisher *Ceryle alcyon* •

PICIFORMES

Picidae

- Woodpecker spp. ◊
Northern Flicker *Colaptes auratus* •

PASSERIFORMES

Hirundinidae

- Tree Swallow *Tachycineta bicolor* •

Corvidae

- Blue Jay *Cyanocitta cristata* ◊
American Crow *Corvus brachyrhynchus* •◊
Common Raven *Corvus corax* •◊

Paridae

- Black-capped Chickadee *Parus atricapillus* •◊

Turdidae

- American Robin *Turdus migratorius* •◊

Mimidae

- Gray Catbird *Dumetella carolinensis* •

Sturnidae

- European Starling *Sturnus vulgaris* •◊

Parulidae

- Yellow-rumped warbler *Dendroica coronata* •◊

Icteridae

- Common Grackle *Quiscalus quiscula* •

Emberizidae

- Savannah Sparrow *Passerculus sandwichensis* ◊
Song Sparrow *Melospiza melodia* •◊
Dark-eyed Junco *Junco hyemalis* ◊
Snow Bunting *Plectrophenax novalis* ◊
Crossbill spp. ◊
Common Redpoll *Carduelis flammea* ◊

were not seen by the observer there, or (2) turned away from the bridge and flew around the north shore of Prince Edward Island to get to the Strait of Canso and cross to the Atlantic shore. Both explanations are

likely although we are unable to determine the relative proportions which might follow either potential route.

There is also the distinct possibility that some scoters may cross the Botsford Peninsula and into Baie

TABLE 2. The numbers of scoters seen in spring 1997 from Money Point at the base of Confederation Bridge in the Cape Jourimain National Wildlife Area.

Date	Time Period (Hrs)	Numbers of Scoters					
		Total	Surf	Black	WW	Unid.	No./hr
14 April	1015–1045	0	–	–	–	–	0.0
"	1145–1215	200	–	–	–	200	400.0
"	1230–1315	9	–	–	–	9	12.0
Mean no./hr.	(2.0 hours)	–	–	–	–	–	137.3
15 April	1100–1130	50	–	–	–	50	100.0
"	1145–1230	0	–	–	–	–	0.0
"	1330–1500	250	125	125	–	–	89.2
Mean no./hr.	(2.75 hrs)	–	–	–	–	–	174.1
16 April	1400–1500	20	–	20	–	–	20.0
Mean no./hr.	(1 hr)	–	–	–	–	–	20.0
17 April	1300–1700	1520	1200	320	–	–	380.0
Mean no./hr.	(4 hrs)	–	–	–	–	–	380.0
18 April	153–1900	95	40	55	–	–	27.1
Mean no./hr.	(3.5 hrs)	–	–	–	–	–	27.1
20 April	1400–1800	56	–	56	–	–	14.0
Mean no./hr.	(4.0 hrs)	–	–	–	–	–	14.0
22 April	1300–2030	180	90	90	–	–	24
Mean no./hr.	(7.5 hrs)	–	–	–	–	–	24.2
23 April	1600–2015	109	88	–	–	21	27.25
Mean no./hr.	(4.25 hrs)	–	–	–	–	–	25.6
26 April	0915–1315	536	58	352	1	125	134
Mean no./hr.	(4 hrs)	–	14.5	88	0.25	31.25	134
26 April	1500–1930	378	50	95	6	227	84.4
Mean no./hr	(4.5 hrs)	–	11.1	21.1	1.3	50.4	84.4
27 April	1500–1930	400	150	100	150	–	88.8
Mean no./hr.	(4.5 hrs)	–	33.3	22.2	33.3	–	88.8
1 May	1200–1400	0	–	–	–	–	0.0
"	1700–1900	183	–	3	16	164	91.5
Mean no./hr.	(4 hrs)	183	–	3	16	164	45.8
Totals & Mean No./hr.	46 hours	3986	1801	1216	173	796	86.7

Verte, New Brunswick, a large bay just south of Cape Tourmentine and the bridge (see Figure 2). For example, one of us (K. B-P.) visited Baie Verte on 8 November 1997, and noted White-winged Scoters “in the hundreds all strung out along and in the bay”. On that same day, very few scoters were observed at Cape Jourimain. This observation suggests that some scoters may cross to Baie Verte over the Botsford Peninsula, between Shemogue Harbour and Baie Verte, and were therefore not recorded by the observer at the base of Confederation Bridge.

In 1990, over 22 hours of field observations, MacKinnon et al. (1991) recorded a total of 1405 scoters migrating through Northumberland Strait in spring and fall. As in the present study, they were unable to identify 41% of these birds to species. Of the 824 that they did identify, 493 (59.8%) were Surf, 191 (23.2%) Black, and 140 (16.9%) White-winged

scoters. The larger proportions of Surf Scoters seen by MacKinnon et al. (1991) were due to the relatively larger numbers of this species seen there in spring.

The total numbers of scoters seen in the fall by MacKinnon et al. (1991) in 1990 and by the observers in the present study, were almost identical (1405 vs 1441 birds, respectively) even though MacKinnon et al. (1991) spent only 14% of the hours spent by the main observer (K. B-P.) in the present study (22 hours over both spring and fall seasons vs 156 hours- fall season only). Hence, the great difference in methodology most likely accounts for the differences between their results.

For example, the migration rate for Surf Scoters on 23 October 1990, was 237 birds/hr (MacKinnon et al. 1991), or six times the rate we recorded (1.3–37.1 birds/hr). The rates recorded for Black Scoters were 18/hour on 12 October (MacKinnon et al. (1991: page

TABLE 3. The numbers of scoters flying to Confederation Bridge in spring 1997 from New Brunswick and the numbers, and percent of those numbers, flying over the bridge.

Date	Total No. Scoters	No. Over Bridge	Per Cent Over Bridge
14 April	209	9	4.3
15 April	300	0	0
16 April	20	0	0
17 April	1520	0	0
18 April	95	47	49.5
20 April	56	2	3.6
22 April	180	180	100.0
23 April	109	21	19.3
26 April (i)	536	92	17.2
26 April (ii)	378	138	36.5
27 April	400	0	0
1 May	183	23	12.6
Total	3986	512	12.8

i) 0915–1315 hrs
ii) 1500–1930 hrs

26, section 4.10.2), and for White-winged Scoters 39/hour on 17 October 1990 (*ibid*). These are closer to the rates computed in 1997 for all three species combined in either New Brunswick or Prince Edward Island.

Using only the data on rates of southward migration for 1990 and 1997, the post-Confederation Bridge results suggest that Surf Scoters were significantly and negatively affected by presence of the bridge but Black Scoters and White-winged Scoters were not. However, here too, the great differences in observation hours between the two projects may be a factor.

Nonetheless, both studies show that the Northumberland Strait was most important to Surf Scoters during fall migration and least to White-winged Scoters. Clearly, the scoters are affected by the presence of the Confederation Bridge and some of the birds treat it as a complete barrier. White-winged Scoters may be the species which has most easily adapted to this change by choosing to cross overland either on the New Brunswick or the Prince Edward Island, as it was the one that appeared to fly across the bridge with the least hesitation.

TABLE 4. The numbers (and mean number/hr) of scoters seen in the fall from Money Point at Cape Jourimain, New Brunswick, in 1997.

Date	Time Period (hrs)	Total	No./hr	Surf		Black		White-winged		Unidentified	
				Total	No./hr	Total	No./hr	Total	No./hr	Total	No./hr
18 Sept.	1400–1700 & 1600–1700 (4)	27	6.8	20	4	–	–	7	1.8	–	–
20 Sept.	0900–1000 & 1030–1200 (2.5)	9	3.6	–	–	9	3.6	–	–	–	–
21 Sept.	1645–1930 (2.75)	39	14.2	5	1.8	10	3.6	–	–	24	8.7
25 Sept.	1400–1530 (1.5)	4	2.7	1	0.7	–	–	–	–	3	2.0
29 Sept.	1100–1300 (2.0)	42	21.0	6	3.0	–	–	11	5.5	25	12.5
2 Oct.	1100–1700 (5)	37	7.4	21	4.2	–	–	16	3.2	–	–
3 Oct.	1300–1615 (3.25)	26	8.0	10	3.1	9	2.8	–	–	7	2.2
6 Oct.	1500–1700 (4)	70	17.5	26	6.5	–	–	–	–	44	22.0
9 Oct.	1200–1600 (4)	107	26.8	48	12.0	5	1.3	–	–	54	13.5
11 Oct.	0830–1300 (4.5)	167	37.1	22	4.9	13	2.9	19	4.2	113	25.1
13 Oct.	1445–1854 (4)	64	16.0	25	6.3	–	–	–	–	39	9.75
14 Oct.	1430–1830 (4)	35	8.8	35	8.8	–	–	–	–	–	–
17 Oct.	0915–1315 (4)	125	31.3	34	8.5	3	0.8	39	9.75	49	12.3
18 Oct.	0835–1300 (4.5)	121	26.9	30	6.7	53	11.8	13	2.9	25	5.6
20 Oct.	0930–1230 (3)	54	18.0	–	–	2	0.7	23	7.7	29	9.7
21 Oct.	1500–1830 (3.5)	5	1.4	3	0.9	1	0.3	–	–	1	0.3
23 Oct.	0900–1300 (4)	24	6.0	24	6.0	–	–	–	–	–	–
25 Oct.	0900–1300 (4)	64	16.0	6	1.5	–	–	20	5.0	38	9.5
26 Oct.	1400–1730 (5.5)	90	25.7	5	1.4	40	11.4	1	0.3	44	12.6
29 Oct.	0900–1300 (4)	89	22.3	17	4.3	36	9.0	5	1.3	31	7.8
30 Oct.	0900–1345 (4.75)	48	10.1	7	1.5	41	8.6	–	–	–	–
1 Nov.	0840–1240 (4)	45	11.3	6	1.5	25	6.3	4	1.0	10	2.5
3 Nov.	0920–1320 (4)	60	15.0	10	2.5	30	7.5	–	–	20	5.0
6 Nov.	0815–1215 (4)	27	6.8	18	4.5	1	0.3	2	0.5	6	1.5
8 Nov.	0815–1215 (4)	12	3.0	1	0.3	–	–	–	–	11	2.8
11 Nov.	1230–1530 (3)	28	9.3	1	0.3	–	–	–	–	27	9.0
13 Nov.	0730–1130 (4)	5	1.3	4	1.0	–	–	–	–	1	0.3
18 Nov.	0935–1335 (4)	17	4.3	1	0.3	12	3.0	–	–	4	1.0
Total	103.75 hours	1441	13.9	386	3.8	290	2.6	160	1.5	605	5.8

TABLE 5. The numbers of scoters flying to Confederation Bridge in fall 1997 from New Brunswick and the numbers and per cent flying over the bridge.

Date	Total No. Soters	No. Over Bridge	Per Cent Over Bridge	Date	Total No. Soters	No. Over Bridge	Per Cent Over Bridge
18 September	27	0	0	21 October	5	0	0
20 September	9	0	0	23 October	24	0	0
21 September	39	0	0	25 October	64	8	12.5
25 September	4	0	0	26 October	90	12	13.3
29 September	42	21	50.0	29 October	89	4	4.5
2 October	37	0	0	30 October	48	7	14.6
3 October	26	0	0	1 November	45	4	8.8
6 October	70	26	37.1	3 November	60	0	0
9 October	107	17	15.9	6 November	27	2	7.4
11 October	167	49	29.3	8 November	12	0	0
13 October	64	13	20.3	11 November	28	0	0
14 October	35	0	0	13 November	5	0	0
17 October	125	70	56.0	18 November	17	0	0
18 October	121	80	66.1	Total (mean)	1441 (51.5)	316 (11.3)	(21.9)
20 October	54	14	25.9				

TABLE 6. The numbers (and numbers per hour) of scoters seen in the fall from Borden Point, Prince Edward Island, in 1997.

Date	Time Period (Hrs)	Numbers of Scoters					No./hr
		Total	Surf	Black	WW	Unid.	
17 October	1045–1100	15	—	—	—	15	60
	1115–1103	0	—	—	—	—	0
	1145–1200	9	—	—	—	9	36
	1215–1230	10	—	—	—	10	40
	1245–1300	3	—	—	—	3	12
Average	(1.25 hrs)						29.6
20 October	1000–1015	0	—	—	—	—	4
	1030–1045	10	9	—	—	1	40
	1115–1130	0	—	—	—	—	0
	1145–1200	4	—	—	4	—	16
	1215–1230	5	—	—	—	5	20
	1245–1300	47	20	—	27	—	188
Average	(1.5 hrs)						44.6
21 October	0915–0930	34	—	—	—	34	136
	0930–0945	4	—	—	—	4	16
	1000–1015	0	—	—	—	—	0
	1015–1030	0	—	—	—	—	0
	1045–1100	0	—	—	—	—	0
	1100–1115	0	—	—	—	—	0
	1115–1130	0	—	—	—	—	0
	1130–1145	0	—	—	—	—	0
	1220–1230	1	—	—	—	1	4
	1230–1245	1	—	—	—	1	4
	1245–1300	1	—	—	—	1	4
Average	(2.45 hrs)						14.9
22 October	0900–1000	20	—	—	—	20	20
	1000–1100	4	—	—	—	4	4
	1100–1200	3	—	—	3	32	35
	1200–1300	2	—	—	—	2	2
Average	0900–1300 (4 hrs)	61	—	—	0.75	14.5	15.3
23 October	0900–1000	0	—	—	—	—	0
	1000–1100	4	—	—	1	3	16
	1100–1200	8	—	—	4	4	32
	1200–1300	3	—	—	—	3	12
Average	0900–1300 (4 hrs)	15	—	—	5	10	15

continued

TABLE 6. *Concluded*

Date	Time Period (Hrs)	Numbers of Scoters					
		Total	Surf	Black	WW	Unid.	No./hr
28 October	0915–1015	24	—	1	—	23	24
	1015–1115	15	—	—	—	15	15
	1115–1215	27	—	—	—	27	27
	1215–1300	21	—	—	—	21	21
Average	0915–1300 (3.75 hrs)	87	—	1	—	86	23.2
29 October	0900–1000	8	—	1	3	4	8
	1000–1100	0	—	—	—	—	0
	1100–1200	0	—	—	—	—	0
	1200–1300	14	—	1	—	13	14
Average	0900–1300 (4 hrs)	22	—	2	3	17	5.5
30 October	1100–1200	2	—	—	—	2	2
Average	1100–1200 (1 hr)	2	—	—	—	2	2
31 October	0930–1030	3	—	—	2	1	3
	1030–1130	4	—	4	—	—	4
	1130–1230	0	—	—	—	—	0
	1230–1300	0	—	—	—	—	0
Average	0930–1300 (4 hrs)	1.75	—	1	0.5	0.25	1.75
3 November	0915–1015	4	—	1	—	3	4
	1015–1115	0	—	—	—	—	0
	1115–1215	0	—	—	—	—	0
	1215–1300	0	—	—	—	—	0
Average	0915–1300 (3.75 hrs)	1	—	0.25	—	0.75	1
4 November	0915–1015	3	—	—	—	3	3
	1015–1115	1	—	1	—	—	1
	1115–1215	1	—	1	—	—	1
	1215–1300	0	—	—	—	—	0
Average	0915–1300 (3.75 hrs)	1	—	0.5	—	0.75	1
6 November	0930–1030	0	—	—	—	—	0
	1030–1130	0	—	—	—	—	0
	1130–1215	0	—	—	—	—	0
Average	0930–1215 (2.75 hrs)	0	—	—	—	—	0
7 November	1015–1115	5	—	—	—	—	5
	1115–1215	10	—	—	—	10	10
	1215–1245	60	—	—	—	60	100
Average	1015–1245 (2.75 hrs)	26	—	—	2	20	38.3
12 November	0900–1000	42	—	—	3	39	42
Average	0900–1000 (1 hr)	42	—	—	3	39	42
19 November	0830–0900	5	—	—	3	2	10
Average	0830–0930 (0.5 hr)	5	—	—	3	2	10
20 November	0815–0845	1	1	—	—	—	2
Average	085–0915 (0.75 hr)	1	1	—	—	—	2
21 November	0815–0845	5	—	—	—	5	10
Average	0815–0915 (0.75 hr)	5	—	—	—	5	10
26 November	0830–0845	0	—	—	—	—	0
Average	0830–0930 (1 hr)	0	—	—	—	—	0
OVERALL TOTALS	41.95 hours	475	30	10	55	380	11.3/hr

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New Plant Records for Prince Edward Island

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MacQuarrie, Kate, and Heidi Schaefer. 2001. New plant records for Prince Edward Island. *Canadian Field-Naturalist* 115(3): 446–450.

The first records of *Apios americana* (Groundnut), *Polystichum braunii* (Braun's Holly Fern), *Hieracium piloselloides* (King Devil) and *Impatiens glandulifera* (Glandular Touch-me-not) from Prince Edward Island are reported. Large numbers of *A. americana* were found in two populations on the Lennox Island Mi'Kmaq reserve, Malpeque Bay, Prince County while *P. braunii* was restricted to a few individuals along the bank of the Mill River, Bloomfield, Prince County. *H. piloselloides* was first identified in retired farmland at Greenwich, Kings County, and *I. glandulifera* was found along the Barbara Weit River at New Annan, Prince County.

Key Words: *Apios americana*, Groundnut, *Polystichum braunii*, Braun's Holly Fern, *Hieracium piloselloides*, King Devil, *Impatiens glandulifera*, Glandular Touch-me-not, Prince Edward Island, new records.

As Canada's smallest and most densely populated province, Prince Edward Island has few unexplored or undisturbed habitats. Since the arrival of European settlers in the early 1700s, land clearing for agriculture, shipbuilding, and habitation has consumed much of the Island's original Acadian forest. It is estimated that by 1900, over 70% of the land had been cleared (P.E.I. Department of Agriculture and Forestry 1997) and much of the remnant forest had been previously burned or harvested in varying degrees. Today, roughly 50% of the province is wooded, but less than one fifth of this resembles the original Acadian upland forest of *Fagus grandifolia* (American Beech), *Betula alleghaniensis* (Yellow Birch), *Acer saccharum* (Sugar Maple), *Acer rubrum* (Red Maple), *Tsuga canadensis* (Eastern Hemlock), *Picea rubens* (Red Spruce), and *Pinus strobus* (White Pine) (Arsenault 1997*).

Despite this history of land use, there is much to be discovered about the flora of Prince Edward Island. While *The Plants of Prince Edward Island* (Catling, Erskine and MacLaren 1985) and *The Rare Vascular Plants of Prince Edward Island* (Day and Catling 1991) remain the primary publications on the topic, many new locations for some of the rarest species have been found in the past two years (MacQuarrie, Schaefer and Schoenrank 1999; MacQuarrie et al. 2000; MacQuarrie, Schaefer, Schoenrank and Lewis 2000*). Creation and revision of a vascular plant tracking list for P.E.I. (Blaney, MacQuarrie and Curley 2000) and the 2000/01 update of the provincial forest inventory are adding to our knowledge of this province's flora.

Recently, two apparently indigenous species previously unknown from Prince Edward Island have been discovered: *Apios americana* (Groundnut), found on Lennox Island on 27 July 1999 and *Polystichum brau-*

nii (Braun's Holly Fern), found in Bloomfield on 12 August 1999. Two additional exotic species have also been identified: *Hieracium piloselloides* (King Devil) found at Greenwich in June 1999 and *Impatiens glandulifera* (Glandular Touch-me-not) found in New Annan in October 1999.

Apios americana (Groundnut)

Located in the western end of Malpeque Bay, Prince County, Lennox Island is home to the Lennox Island First Nation of Mi'Kmaq peoples (Figure 1). Encompassing approximately 540 hectares, Lennox Island is among the largest of the province's many offshore islands. Nearly two-thirds of the island is forested, primarily in disturbed hardwood characterized by *Acer rubrum* (Red Maple), *Betula papyrifera* (White Birch), *Populus tremuloides* (Trembling Aspen) and *P. grandidentata* (Large-toothed Aspen). There are pockets of *Picea mariana* (Black Spruce) scattered throughout, as well as sandy beaches on the north shore and tidal salt marshes on the south. Non-



FIGURE 1. Locations of four new provincial floral records for Prince Edward Island.

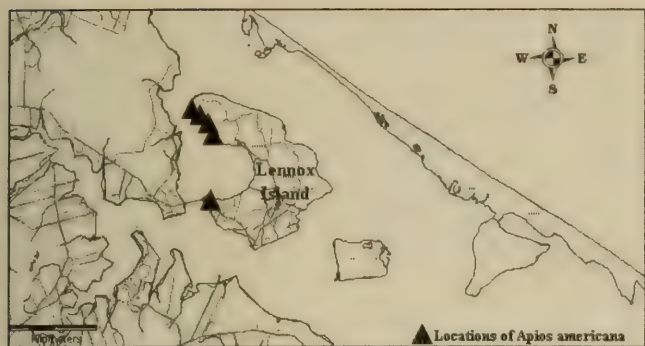


FIGURE 2. Locations of *Apios americana* on Lennox Island, Prince County, Prince Edward Island.

forested land is a combination of inhabited areas and lands being used for commercial blueberry production. The topography is generally flat, with the highest elevation only eight metres. Soils range from sand to sand phase till, with a handful of calcareous mudstone breccia lenses (Prest 1973).

Apios americana was first found in the northwestern end of Lennox Island, in a region known locally as “the Cove” (46°37’30”N, 63°52’30”W) (Figure 2). The first specimen was identified in an area where the disturbed hardwood forest blended into *Picea glauca* (White Spruce), *P. mariana*, and *Abies balsamea* (Balsam Fir) which in turn bordered the coastal salt marsh. The plant was growing vine-like among the conifers, climbing to heights in excess of two metres. Although not in flower, the plant was easily identified by its trailing growth and pinnate, entire leaves with five lanceolate leaflets. Leaflets varied from 2 to 4 centimetres in width and 4 to 6.4 cm in length on the specimens collected. The root was found to have the characteristic tubers from which the plant gets its common name, Groundnut.

A second trip to Lennox Island on 9 August 1999 found *Apios americana* fully in flower (Figure 3). During this second visit, individual plants were photographed and collected, the extent of the population was roughly mapped and a second population was found near the southwestern tip of the island (43°36’30”N, 63°52’30”W) (Figure 2).

The first population was found to extend into the upper salt marsh, growing in areas of dense and vigorous *Toxicodendron rydbergii* (Poison Ivy). At the transition zone between marsh and woodland, *Apios* was growing up all available vegetation including *Myrica pensylvanica* (Bayberry), *Nemopanthus mucronata* (False Holly), *Prunus pensylvanica* (Pin Cherry), *Viburnum nudum* (Wild Raisin) and *Rosa* spp. (wild roses). The population extended along this coastal area for more than 750 metres, varying in width from a few to nearly 100 metres. Other plants of this area included the provincially rare *Elymus trachycaulus* (Slender Wheat Grass), *Distichlis spicata* (Seashore Salt Grass), and *Teucrium canadense* (American Germander). Voucher material for each

of these species was collected and remains on file with Island Nature Trust.

The second population was growing in a roadside ditch in the southwestern region of the island, extending up the “Welcome to Lennox Island” sign. It covered a much smaller area than the aforementioned population, most likely because regular roadside maintenance has prevented its spread.

During the potato famine of 1845, *Apios* was considered as a possible blight resistant substitute for *Solanum tuberosum* (Potato) (Reynolds et al 1990). It was at this time that Island geologist Abraham Gesner visited the islands of Richmond (now Malpeque) Bay in search of native plants that could be cultivated as substitutes for the blight-stricken potato. In a letter to *The Islander* on 12 August 1846, Gesner wrote of a plant shown to him by the Mi’Kmaq people:

“[Saa-gaa-ban] was found on several of the Islands in Richmond Bay, but is most plentiful at the bases of the sand mounds of Fish Island. Its favourite site seems to be along the skirts of the sandhills that form the lagoons along the coast, where it is nourished by decomposed sea weed and shells. It occurs in the midst of matted grass and wild tares, and frequently occupies patches of several square rods. The leaf of the saa- gaa-ban resembles the leaf of the cultivated potato. The stock is like a small



FIGURE 3. *Apios americana* on Lennox Island, Prince Edward Island, 9 August 1999. Photo by J. Waddell, Island Nature Trust.

vine; the roots are situated two inches below the surface of the soil, and the bulbs of oval figures, are strung together like beads, being attached to each other by a strong ligament. They are of a blackish brown color, and also resemble potatoes in their general character, being dry, farinaceous and nutritive”.

Gesner's saa-gaa-ban has characteristics of *Apios* and occupies habitat similar to that in which it was found on Lennox Island, also in Malpeque Bay. Hinds (2000) reports *Segabun* as a Mi'Kmaq name for *Apios* and this plant is well-known as a food of eastern North America's early aboriginal peoples who both gathered it from the wild and transplanted it near campsites (Reynolds et al. 1990). It is possible that this accounts for the species' presence on Lennox Island.

Apios is common in southwestern Nova Scotia and scattered elsewhere in that province (Zinck 1998). In New Brunswick, it is scattered in southern areas, reaching as far north as Kouchibouguac National Park (Hinds 2000). Its range extends into southern Quebec and Ontario (Scoggan 1979) and the eastern half of the United States to the Gulf of Mexico (Reynolds et al. 1990).

Voucher material and photographs of the newly-discovered Prince Edward Island population are on file with Island Nature Trust. A voucher specimen has been sent to the Department of Agriculture Herbarium in Ottawa.

Polystichum braunii (Braun's Holly Fern)

Polystichum braunii is an easily recognized fern (Figure 4). Its stipe is conspicuously chaffy, covered in light brown to golden scales. The blade is leathery at both ends, twice pinnate and chaffy beneath and on the rachis. Each pinnule has spiny edges and a sharp lobe at its base, characteristic of the holly ferns. Sori are arranged in two ranks along the midrib and spores are present from June to September (Zinck 1998). In Canada, *P. braunii* is found from Newfoundland west to southern Ontario,



FIGURE 4. *Polystichum braunii* at Mill River, Prince Edward Island, 20 September 1999. Photo by J. Waddell, Island Nature Trust.

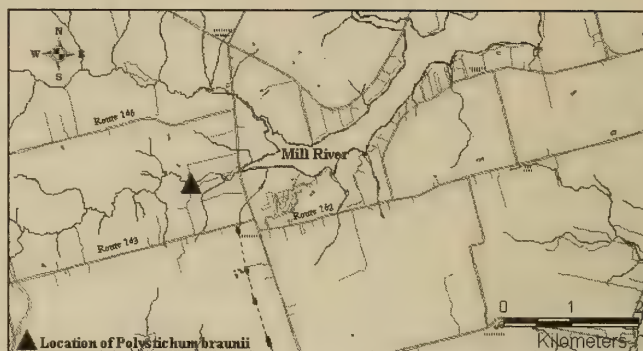


FIGURE 5. Location of *Polystichum braunii* along the Mill River, Bloomfield, Prince County, Prince Edward Island.

while in the United States it ranges from Maine, south to Connecticut and west to Wisconsin. It has also been recorded in St. Pierre and Miquelon. Western populations are known in British Columbia, Yukon, Alaska and Idaho (Kartesz 1999). *P. braunii* is not considered common anywhere in its North American range. Kartesz (1999) cites *Polystichum braunii* as rare in Idaho, Minnesota, Wisconsin, Pennsylvania, Massachusetts and Ontario, and it is listed as endangered in Minnesota (Minnesota Department of Natural Resources 1999. www.dnr.state.mn.us/fish_and_wildlife/endangered_species/envasend.ht) and threatened in Wisconsin (Wisconsin Department of Natural Resources 1999. www.dnr.state.wi.us/org/land/er/factsheets/plants/brafern.htm).

In neighbouring Nova Scotia, Roland (1941) recorded *P. braunii* only in the richest hardwood areas which include lands along the Bay of Fundy, in the Cobequid Hills and in the hardwood areas of Inverness and Victoria counties of Cape Breton. Nichols (1918) found *P. braunii* characteristic of the deciduous climax forest, sandy flood plains and especially in the ravines of northern Cape Breton. Zinck (1998) added seepy hillsides as a habitat type for this species. *P. braunii* is considered uncommon to rare in New Brunswick, where it is associated with calcareous soils (Hinds 2000). With the exception of soil type, the habitat in which the Prince Edward Island specimens were found is consistent with records from the mainland.

Approximately six to eight specimens of *P. braunii* were found in a steeply sloped area of mature forest along the Mill River in Bloomfield, Prince County (46°44'30"N, 64°11'30"W) (Figure 5). The topography of the Mill River area is primarily gently rolling hills that rarely exceed 45 metres in height, however the river itself flows through a steep ravine en route to Cascumpec Bay on the Island's north shore. Land use in the area is divided between forest (40%) and agriculture (60%), with forest dominating the upper watershed area and lands along the river itself. The soils are classed as clay and clay-phase till

and the area in which the fern was found is the largest of a very few pockets of ablation moraine in Prince County (Prest 1973).

Information based on Samuel Holland's 1767 survey of Prince Edward Island suggests that land in the Mill River area was classed as good farmland. By 1833, this was among the most extensively cleared areas in the province (Clark 1959). Clark's map of forest cover prior to land clearances delineates a hardwood forest association more typical of Central P.E.I. in this western area of the province. This pocket of hardwood forest was an oddity among what Clark called the White Cedar association which dominated most of the western end of the Island. Maps of the Mill River area estimating forest cover circa 1900 (P.E.I. Department of Agriculture and Forestry 1997) show that while much of the land was cleared, pockets of forest remained in the general area where *P. braunii* was found.

The ravine in which the fern was found includes trees typical of the Acadian Forest: *Betula alleghaniensis*, *Fagus grandifolia*, *Acer saccharum* and *Tsuga canadensis*. The size of these trees, the extreme slope, and the estimates of forest cover in this area a century ago, suggest that this land has never been cleared. This is consistent with the knowledge that *P. braunii* is sensitive to forest harvest practices (Wisconsin Department of Natural Resources 1999. www.dnr.state.wi.us/org/land/er/factsheets/plants/brafern.htm). It is probable that *P. braunii* was once more widespread on P.E.I., and that the specimens found in 1999 remained simply because they were restricted to an area too difficult to harvest.

In addition to the new Island record, Mill River is also the location for other provincially rare vascular plants. *Clematis virginiana* (Virgin's Bower), *Laportea canadensis* (Wood Nettle) and *Solidago flexicaulis* (Zigzag Goldenrod) were all found in the immediate area, adding to its interest and significance. Day and Catling (1991) report that Erskine's specimen of *L. canadensis* had been lost; Zinck (1998) reports this species as absent from Prince Edward Island. Voucher material for *L. canadensis*, *C. virginiana* and *P. braunii* is on file with Island Nature Trust, and a voucher specimen for the latter species has been forwarded to the Department of Agriculture Herbarium in Ottawa.

Impatiens glandulifera (Glandular Touch-me-not) and *Hieracium piloselloides* (King Devil)

In addition to the two indigenous species, we have identified two exotic species that are absent from the Island's floral literature. *Hieracium piloselloides* (King Devil) was found by the authors in retired farmland at Greenwich, Prince Edward Island National Park, Kings County, in June 1998. *Impatiens glandulifera* (Touch-me-not) was found and collected in New Annan, Prince County, by Peter Stewart on 6

October 1999, and subsequently identified by Kate MacQuarrie. Voucher material is on file with Island Nature Trust.

Discussion

There are few current threats to either *Apios americana* or *Polystichum braunii*. *A. americana* is not in a region of Lennox Island that is likely to be under pressure for commercial blueberry production, housing, or other development. Preliminary contact with the Band Council suggests that there is an interest in conservation of this species on the reserve, and we look forward to working with band members in an effort to identify the plant's provenance on Lennox Island.

The reasonably inaccessible location of *P. braunii* suggests that it will not be disturbed by logging or development, although recreational use of the area may be a concern. Local anglers have worn a path through the *Laportea canadensis*, not far from the location of *P. braunii*. As community interest in watershed enhancement increases across P.E.I., it is possible that stream clearing activities designed to improve fish habitat could result in elimination of the very few fern individuals found. We have advised the provincial watershed enhancement coordinator of the presence of the fern and rare vascular plants along this system.

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Status of the Deltoid Balsamroot, *Balsamorhiza deltoidea* (Asteraceae) in Canada[†]

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Douglas, George W., and Michael Ryan. 2001. Status of the Deltoid Balsamroot, *Balsamorhiza deltoidea* (Asteraceae) in Canada. *Canadian Field-Naturalist* 115(3): 451–454.

In Canada, Deltoid Balsamroot, *Balsamorhiza deltoidea* has been collected only on southeastern Vancouver Island. Populations have been confirmed at six sites in recent years while the species has probably been extirpated at eight other previous collection sites. The confirmed populations collectively represent the northern range limit of *B. deltoidea*. Population sizes range from five to 1600 plants. Threats to the existing populations include habitat destruction and the increasing invasion of introduced species. In addition, sites in ecological reserves or municipal and regional parks are sometimes at risk due to management activities. Considering these threats to the habitat of *B. deltoidea*, we recommend a status of threatened.

Key Words: Deltoid Balsamroot, *Balsamorhiza deltoidea*, British Columbia, threatened, distribution, population size.

The Deltoid Balsamroot, *Balsamorhiza deltoidea* Nuttall is a member of a genus of about 12 species found in western North America (Cronquist 1955). Only two of these species, the latter and Arrowleaf Balsamroot (*Balsamorhiza sagittata*), occur in British Columbia and Canada (Scoggan 1979; Douglas et al. 1998b). Taxonomy and nomenclature follows Douglas et al. (1994, 1998b, 1998c, 1999a, 1999b, 2000, 2001).

Balsamorhiza deltoidea is a leafy, ascending plant, ranging from 20–100 cm tall with long-stalked, triangular, stiff-hairy and glandular leaves with the blades 10–50 cm long and 10–20 cm wide (Figure 1, Douglas et al. 1998b). The few to several flower heads are borne on long stalks. The involucral bracts are lanceolate to oblong-lanceolate and the 13 to 21 ray flowers are bright yellow. The numerous disk flowers are also yellow. The fruits (achenes) are 7–8 mm long, smooth and lack a pappus.

Distribution

Balsamorhiza deltoidea occurs on the west coast of North America from southwestern British Columbia along the western slopes of the Cascade Mountains in Washington and Oregon to the western slopes of the Sierra Nevada in California. In Canada, it is restricted

to southeastern Vancouver Island (Figure 2, Douglas et al. 1998a).

Habitat

Balsamorhiza deltoidea populations are restricted mainly to very dry, exposed or partially shaded sites where soils are shallow. Trees such as Garry Oak (*Quercus garryana*) are frequent. Other associated species include: Scotch Broom (*Cytisus scoparius*), Snowberry (*Symphoricarpos albus*), Broad-leaved Stonecrop (*Sedum spathifolium*), Nooding Onion (*Allium cernuum*), Menzies' Larkspur (*Delphinium menziesii*), Sweet Vernalgrass (*Anthoxanthum odoratum*), and several species of Brome (*Bromus*). Two of the populations are on quite different sites from the latter. The largest population, at Campbell River, dominates an open meadow on marine sediments adjacent to the ocean (Figure 3) while another population, on Mt. Tzuhelem, occurs in a relatively moist ravine with *Symphoricarpos albus* and *Viola prae-morsa* ssp. *praemorsa*.

General Biology

Balsamorhiza deltoidea emerges in the spring from the perennial taproot and flowers by early summer. By mid-summer, when drought conditions are prevalent, seed set has occurred and the leaves wither and turn brown. Although seeds are usually relatively easy to germinate, the cultivation of young plants in the Victoria area appears to be difficult since they seem to be very sensitive to soil moisture conditions and predators during the growing season. Compared to the large number of flowers comprising the floral head, viable seed production is low. No information is available regarding the population

[†]This paper is based primarily on a COSEWIC status report by the authors. It has been revised to include more recent information. The species was designated threatened by COSEWIC in April 1996. COSEWIC Reports are available from the COSEWIC Secretariat, c/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3 Canada.

TABLE 1. Location of *Balsamorhiza deltoidea* sites in British Columbia.

Collection Site	Last Observation	Observer	Population (number/area)
Tolmie Farm (Victoria)	1891	Newcombe	Extirpated
Lost Lake (Victoria)	1916	Newcombe	Extirpated
Lake Hill (Victoria)	1926	Walker	Extirpated
Royal Oak (Victoria)	1935	Goddard	Extirpated
Campbell River, south of	1959	Beamish	Extirpated
Witty's Lagoon (Victoria)	1965	Carl	Extirpated
Fort Rodd Hill (Victoria)	1966	Ashlee	Extirpated
Portage Inlet (Victoria)	1976	Brayshaw	Extirpated
Francis-King Park, south of (Victoria)	1993	Ryan	70/20 m ²
Mill Hill (Victoria)	1998	Douglas	50/100 m ²
Tyee Spit (Campbell River)	1998	Douglas	1600+/1260 m ²
Mount Tzuhalem (Duncan)	1999	Douglas	55/40 m ²
Thetis Lake (Victoria)	1999	Douglas	72/60 m ²
Beacon Hill (Victoria)	1999	Douglas	5/1 m ²

dynamics of this species including the extent to which seed remains viable in the soil, the frequency with which recruitment occurs from established seedlings, and the average life-span of mature plants.

Population Size and Trends

Of the 14 Canadian sites from which *Balsamorhiza deltoidea* has been collected, only six sites have been confirmed recently (Table 1). The status of the species at the additional sites remains uncertain but it is believed that all of the populations and some of the sites have been extirpated. Little is known regarding the specific size of past populations although it is likely some of these were larger at one time. The largest population (1600 plants) is located on an Indian Reserve near Campbell River and has remained stable between 1992 and 1999. All other populations number less than 250 plants in total. Three of the sites (Beacon Hill, Mt. Tzuhalem and Tyee Spit), visited on a yearly basis between 1992 and 1999, have remained stable, or, in the case of Mt. Tzuhalem, have increased slightly in numbers since 1992.

Limiting Factors

The most direct and immediate threat to *Balsamorhiza deltoidea* is habitat destruction. This is of particular concern on the rock outcrops often associated with *Quercus garryana* stands that are limited to the southeastern side of Vancouver Island. This type of vegetation is believed to have been much more common before European settlement. Its destruction has continued to the present resulting in the elimination of many sites occurring outside parks or ecological reserves. At this time, pressures to develop the remaining unprotected *Quercus garryana* stands for the expansion of the urban infrastructure of Victoria, and other population centres on Vancouver Island, are intense. The population at the

Campbell River Indian Reserve may currently be under even greater threat since new development plans are under consideration for the site.

The suppression of fire within the past century may have also contributed to the demise of *Balsamorhiza deltoidea* populations. Many of the sites in which this species has been collected may have been maintained in the past as a result of periodic fires, both natural and intentionally set, aboriginal peoples probably set fire to these stands to maintain them as an important habitat for wildlife and for the continued harvesting of Camas (*Camassia* spp.), a member of the Liliaceae (Roemer 1972; Turner and Bell 1971). Since that time, these sites have experienced little disturbance, resulting in the invasion of many other species, especially introductions.

The introduction of exotic species has resulted in substantial changes, not only to the grass-dominated meadows associated with *Quercus garryana*, but also to the dry, rocky sites north and west of Victoria where *Balsamorhiza deltoidea* has been collected in the past. One of the most devastating species, over the past 100 years, is *Cytisus scoparius* which has become a dominant shrub on dry, exposed sites throughout much of eastern Vancouver Island and the Gulf Islands. Much of the vegetation is also now dominated by introduced grasses. These species include Early hairgrass (*Aira praecox*), *Anthoxanthum odoratum*, Hedgehog Dogtail (*Cynosurus echinatus*) and Orchard Grass (*Dactylis glomerata*).

Special Significance of the Species

Balsamorhiza deltoidea is a member of a relatively large group of species with a Western Cordilleran range that have their northern limits in western Canada. The significance of these peripheral populations, especially with respect to their genetic characteristics, has yet to be studied adequately. This and a



Figure 1. Illustration of *Balsamorhiza deltoidea*. (Line drawing by Elizabeth J. Stephen in Douglas et al. (1998a, 1998b).

number of other species with similar ranges may prove to be a fruitful subjects for genetic research.

Protection

Balsamorhiza deltoidea has been globally ranked by The Nature Conservancy of the United States as “G5,” or “common to very common with an existence that has been demonstrated to be secure and essentially ineradicable under present conditions.”

The British Columbia Conservation Data Centre has ranked this species as S2 and placed it on the Ministry of Environment, Lands and Parks Red list (Douglas et al 1998a). The S2 rank indicates that the plant is “imperiled because of rarity (typically 6–20 extant occurrences or few remaining individuals) or because of some factor(s) making it vulnerable to extirpation or extinction”. *Balsamorhiza deltoidea* has a national rank in Canada of N2.

There is no specific legislation for the protection of rare and endangered vascular plants in British Columbia. Some populations of *Balsamorhiza deltoidea* are protected to a certain extent by their location on public property. Of all the *B. deltoidea* sites known in British Columbia, those located on Mount Tzuhalem receive the greatest degree of protection

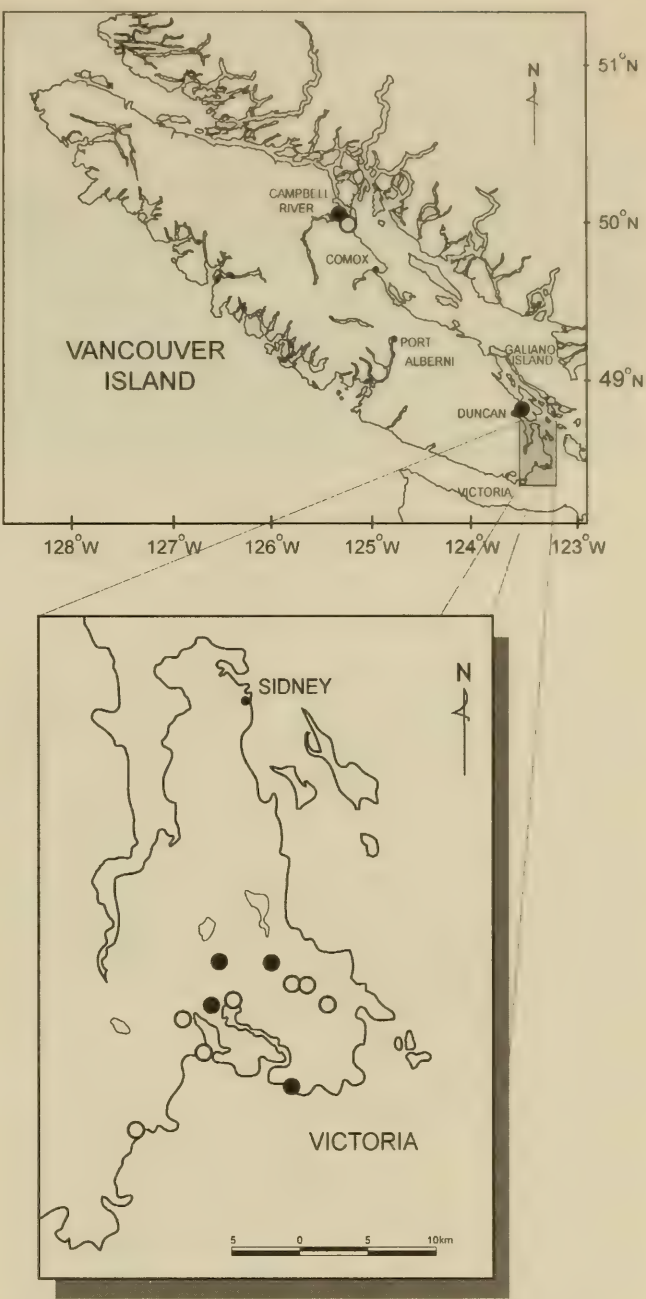


FIGURE 2. Distribution of *Balsamorhiza deltoidea* in British Columbia (o – extirpated sites, • – recently confirmed sites).

because of their location within an ecological reserve. The Mount Tzuhalem Ecological Reserve encompasses 18 ha of *Quercus garryana* woodland, spring-flowering meadows, and rock outcrops which have been preserved to represent an example of *Q. garryana* woodlands and associated spring-flowering herbs. Unfortunately, *Cytisus scoparius* has become a dominant species at this site and threatens many herbaceous species, including *Balsamorhiza deltoidea*

A number of extant *Balsamorhiza deltoidea* sites are in small regional parks in the Greater Victoria area. These include populations at Beacon Hill, Mill Hill and Thetis Lake. These parks receive little active management, at least with respect to their rare



FIGURE 3. A dense population of *Balsamorhiza deltoidea* on the Campbell River Indian Reserve. (Photo by Sylvia M. Douglas).

plants. Park enhancement projects, road and trail developments and heavy recreational use by humans often result in the destruction of the native vegetation and rare plant species. The largest population (1600 plants), located on an Indian Reserve at Campbell River, is also the most seriously threatened population. The loss of *Balsamorhiza deltoidea* at this site seriously jeopardizes the future of this species in Canada considering that the number of individuals comprising the remaining populations number less than 250 plants in total.

Evaluation of Status

Balsamorhiza deltoidea is considered, by the British Columbia Conservation Data Centre (Douglas et al. 1998a) to be endangered in Canada and is known only from six extant colonies restricted to southeastern Vancouver Island. Except for the large population (1600 plants) at Campbell River, the remaining populations range from five to 72 individuals and may be in danger of extirpation. The prognosis for this species is not good considering the threats posed by potential developments and by aggressive competitive species such as *Cytisus scoparius* which dominate many suitable habitats and directly threaten some colonies. Therefore, even if all colonies were protected from human interference, many colonies may eventually disappear as a result of aggressive introduced species. Likewise, much of the *Quercus garryana* vegetation in which *Balsamorhiza deltoidea* is usually found has been extensively altered or destroyed, thus limiting the potential of this species to become established at new sites.

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Status of Scouler's Corydalis, *Corydalis scouleri* (Fumariaceae) in Canada†

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Douglas, George W., and Judy A. Jamison. 2001. Status of Scouler's Corydalis, *Corydalis scouleri* (Fumariaceae) in Canada. *Canadian Field-Naturalist* 115(3): 455–459.

In Canada, *Corydalis scouleri* is restricted to the Klanawa River/Nitinat River watersheds on southwestern Vancouver Island. There are 20 known populations of *Corydalis scouleri* in British Columbia, 19 of which were confirmed in the 1997/1998 field season. One site in the Klanawa River valley, reported in 1992 was not visited. Historical growth or decline in size of populations is unknown. Existing populations represent the northern range limits of *C. scouleri*. British Columbia populations of this species occur in an area that is subject to human disturbance in the form of extensive logging operations, as well as natural disturbance in the form of erosional damage from flooding.

Key Words: Scouler's Corydalis, *Corydalis scouleri*, British Columbia, threatened, distribution, population sizes.

Scouler's Corydalis, *Corydalis scouleri* Hook., is a member of a cosmopolitan genus of about 100 species, mostly in the Northern Hemisphere (Hitchcock et al. 1969). Ownbey (1947), in his monograph of the genus *Corydalis*, notes that annual species predominate in North America. Scoggan (1979) reports five species indigenous to Canada, of which three are annuals or biennials. Four of these five species occur in British Columbia: *Corydalis aurea* and *C. sempervirens* are annuals or biennials, while *C. pauciflora* and *C. scouleri* are perennials (Douglas et al. 1999a).

Corydalis scouleri is a tall (60–120 cm), rhizomatous perennial with hollow, somewhat branched stems (Figure 1). Three blue-green, glaucous, tri- to quadripinnate leaves project near or above the middle of the stem, the lowest often 20–30 cm long (Figure 1). There is a delicate terminal raceme of 15–20 rosy-pink zygomorphic flowers. These flowers are 2–3 cm long and have two lateral outer petals, one spurred or hooded, and two inner, dorsi-ventrally placed petals opposite the quickly deciduous sepals. The bilobed stigma and six stamens, fused in two groups alternating with the petals, are sheltered by a second hood formed by the inner petals. The bicarpellate capsule separates elastically when jarred, scattering the seeds a considerable distance. For each plant, the large dissected leaves form a delicate blue-green canopy,

which intermingles in dense stands with other canopies to form a raised carpet of lush foliage about 1 m above the forest floor. The genus name is Greek for “crested lark”, possibly referring to the shape of the flower.

Distribution

Corydalis scouleri is limited in distribution to the region west of the Cascades (mostly coastal) from northwestern Oregon (near Tillamook) northward through Washington's Olympic Peninsula to southwestern Vancouver Island (Ownbey 1947; Hitchcock et al. 1969; Douglas et al. 1999a). In Canada, known sites are limited to the Klanawa River/Nitinat River watersheds (Figure 2; Douglas et al. 1999a). There has also been a recent report from the upper headwaters of the Cowichan River, about 0.5 km east of the Nitinat River watershed, but this has yet to be confirmed. Another report from the Saanich Peninsula (Szczawinsky and Harrison 1973) has been refuted by Pavlick (1989), who reidentified the specimen to another species.

Habitat

Lush stands of *C. scouleri* are invariably found in wet, cool habitats associated with watercourses — from moderately large rivers to small tributary streams. Sites range in elevation from sea level to close to 1000 m; in British Columbia the highest elevation is about 200 m, the lowest about 5 m. Fine floodplain silts as well as coarser floodplain materials provide ideal habitat for *C. scouleri*. Typical overstory trees include old-growth Bigleaf Maple (*Acer macrophyllum*) and Sitka Spruce (*Picea sitchensis*), as well as Red Alder (*Alnus rubra*), Western Hemlock (*Tsuga heterophylla*) and Western

†This is a Status Report of a species restricted in Canada to British Columbia. This report has been submitted to the National Committee on the Status of Endangered Wildlife in Canada (COSEWIC), but a status designation has not yet been made.

Redcedar (*Thuja plicata*). Major associates in the understory include Western Swordfern (*Polystichum munitum*), Devil's Club (*Oplopanax horridus*), Red Elderberry (*Sambucus racemosa*), Palmate Coltsfoot (*Petasites frigidus* var. *palmarum*), Stink Currant (*Ribes bracteosum*) and Salmonberry (*Rubus spectabilis*). The climate is cool and mesothermal, and these plant communities are commonly found in early seral forests in a nitrogen-rich moder and mull humus ranging from merely moist to very wet. In regions where *Corydalis scouleri* is locally abundant, such as lower elevations of Washington State's Mt. Rainier National Park (Brockman 1947) and the Nitinat River watershed, high annual precipitation is also characteristic.

General Biology

Corydalis scouleri is a perennial herb producing annual stems apically from thick rhizomes. Single clones have been identified by the authors with numerous annual stems spreading for at least tens of square meters. Only a single leaf is produced annually until the plants reach flowering age, which apparently only occurs after four or more years. Flowering in *C. scouleri* takes place in late spring to early summer, usually May and June in the Nitinat River watershed. Both anthers and stigma are enclosed by the determinately shaped and arranged petals, and flowers of all species studied by Ownbey (1947) show evidence of germination of the pollen that is clustered around the stigma. Therefore, self-fertilization in *C. scouleri* is a distinct possibility. Although Liden (1986) reports that most of the species in the tribe Corydaleae (to which *Corydalis* belongs) are strongly self-sterile; no studies are known to have investigated the status of *C. scouleri* in this regard. The species reproduces very well asexually by underground rhizomes and is capable of sexual reproduction by seed. However, it is known that sometimes only the terminal flower of the raceme develops (Hitchcock et al. 1969), and this would severely compromise total seed production. In transplanting rhizomes to suitable habitats, material from different clones should be chosen; planting sexually produced seed would ensure a multiclone population that, consequently, could itself reproduce sexually.

Corydalis scouleri is a perennial, rhizomatous herb that, in addition to reproducing asexually to form large clones, has the potential for considerable sexual reproduction: each flower in the raceme of 15–20 flowers has two multiseeded carpels. Although *C. scouleri*'s would seem to be fairly common, field surveys of potential sites in seemingly ideal habitats have yielded no occurrences outside the immediate Nitinat River/Klanawa River region on Vancouver Island. That a number of pollinators visit *C. scouleri* indicates the likelihood of cross-fer-

tilization; however, since few flowers develop, this may well not be an effective means of reproduction. Pollination experiments indicated that *Corydalis ambigua*, a spring ephemeral species, is self-incompatible; moreover, seed production was increased by a few bee visits of long duration (over 60 seconds), whereas it seemed unaffected by many short visits (less than 60 seconds). Furthermore, the observation that plants with larger inflorescences were visited more often argues for natural selection for a larger inflorescence (Onara and Higashi 1994). Ideal habitat for *C. scouleri* appears to be perennially moist streamside or riverside floodplain soils that are often very fine and silty, although sometimes coarser. Periodic flooding likely facilitates seed or rhizome dispersal.

Population Size and Trends

There are 20 known populations of *Corydalis scouleri* in the Nitinat River/Klanawa River watersheds, 19 of which were confirmed in the 1997/1998 field season (Table 1). Population numbers range from a single plant to several thousand stems stretching over a 0.5 ha area. Several extremely large populations were documented, always in perennially moist riverbank silt. However, no new sites were found farther north along nearby watercourses that offer similar habitats. Pavlick (1989) searched along the Gordon and San Juan drainages without locating additional populations of *Corydalis scouleri*. Historical growth or decline in size of populations is unknown.

Limiting Factors

Extensive logging operations in the Nitinat and Klanawa River Valleys pose the greatest threat to extant populations of *C. scouleri*. A formidable network of logging roads keeps the region open to heavy equipment and tourist traffic alike. Roads require bridges across watercourses, which in turn threatens *C. scouleri* populations along the watercourse—not only when the bridge is constructed but also when tourists gain access to the riverbank to hunt, fish, or hike. Catastrophic flooding could also pose a threat to *C. scouleri* populations, although as mentioned earlier, the plants could also achieve propagation by more moderate flood dispersal. There is a dearth of research evidence suggesting low genetic diversity as a threat to the survival of extant *C. scouleri* populations; however, as suggested in this report, extensive rhizomatous growth accompanied by ineffectual sexual reproduction could be a limiting factor in the species' long-term survival. Lack of genetic heterogeneity in a species can lead to such threats as reduced resistance to disease.

Special Significance of the Species

Gardeners in both North America and Europe value highly several species of *Corydalis* for both



FIGURE 1. Illustration of *Corydalis scouleri* (Line drawing by Jane Lee Ling in Douglas et al. [1998a, 1999a]).

flowers and foliage. Ownbey (1947), in his monograph on the genus noted that European gardeners were using *Corydalis scouleri*, *C. aurea*, and *C. sempervirens*. Cultivation of a rare species for its aesthetic value is, of course, to be encouraged. In addition, the alkaloidal properties of a large number of members of both the fumitory and the closely related poppy family are of great interest to plant taxonomists, plant chemists, and agronomists. Each species has been found to contain a unique set of alkaloids, some of which are common to other species, but not in the same combinations. Agronomists consider these properties significant in that they probably render the plants toxic to livestock; a bitter taste likely makes them unpalatable in any event (Ownbey 1947).

Protection

There is no specific legislation for the protection of rare native vascular plant species in British Columbia. The British Columbia Conservation Data Centre has ranked this species as S2 and placed it on the Ministry of Environment, Lands and Parks Red list (Douglas et al. 1998a). The S2 rank is that of The Nature Conservancy, United States and indicates the species is “imperiled because of rarity (typically 6–20 extant occurrences or few remaining individu-

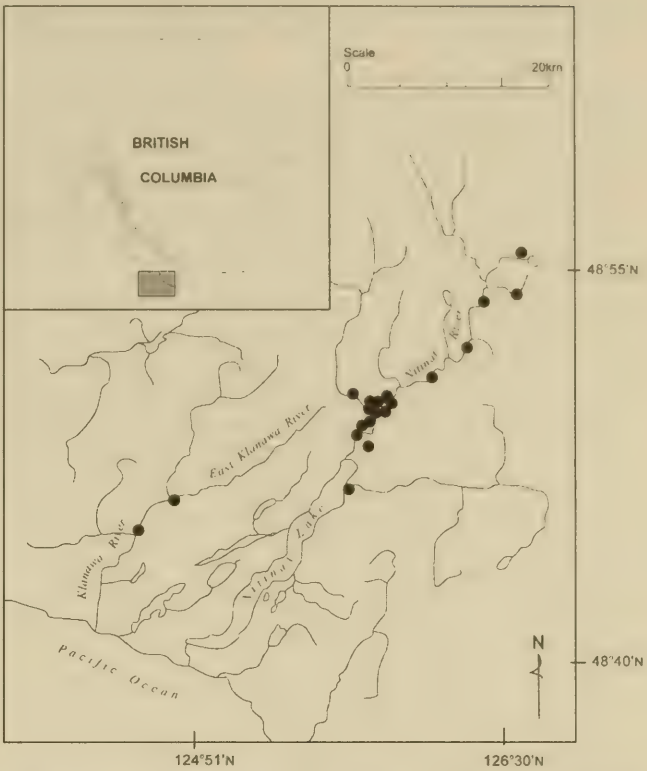


FIGURE 2. Distribution of *Corydalis scouleri* in British Columbia (• - recently confirmed sites).

als) or because of some factor(s) making it vulnerable to extirpation or extinction.”

It has been globally ranked by The Nature Conservancy of the United States as G4. The G4 rank indicates that it is “frequent to common (greater than 100 occurrences); apparently secure but may have a restricted distribution; or there may be perceived future threats.”

Evaluation of Status

Corydalis scouleri occurs rarely in British Columbia in wet, cool, usually shady habitats. As yet we cannot confirm its distribution beyond the Nitinat River/Klanawa River watersheds, where several large populations have been documented (Table 1). These lands are within the South Island forest district, and are owned and administered by timber companies such as Timber West. Responsible logging practices that leave an anti-erosion margin along watercourses should spare most known British Columbia populations of *C. scouleri*, which are apparently limited to streambank and riverbench sites. Propagation of plants (preferably seedlings rather than rhizome cuttings to preserve genetic diversity) from populations that do come under threat would be desirable. In addition, ecological and genetic studies of *C. scouleri* populations would add considerably to our knowledge regarding the reasons for the rarity of this species, thus increasing the potential for conserving viable populations.

TABLE 1. Locations and population sizes of *Corydalis scouleri* sites in British Columbia.

Collection Site	Last Observation	Collector/Observer	Population (Number of stems/area)
Nitinat watershed			
Old Camp 3 road (old Nitinat campsite)	1997	Jamison	16/60 m ²
Nitinat Lake Road, 1 km west of Vernon Creek	1997	Jamison	1100/4000 m ²
Nitinat River, ca. 5 km northeast of northeast end of Nitinat Lake	1997	Jamison	3000/2.7 ha
Caycuse River, mouth of	1997	Jamison	500–700/4000 m ²
Nitinat Lake Road, north of motel	1997	Jamison	100/100 m ²
Nitinat Lake/Bamfield–Carmanah road junction, south of	1997	Jamison	570/1950 m ²
Nitinat Lake Road, northwest of motel	1997	Jamison	1300/3250 m ²
Nitinat River Road, north of visitor centre cut-off	1997	Jamison	100/60 m ²
Nitinat Lake, northwest side, southwest of hatchery turnoff, site A	1997	Jamison	400/2020 m ²
Nitinat Lake, northwest side, southwest of hatchery turnoff, site B	1997	Jamison	1000+/1000 m ²
Nitinat Lake, northwest side, southwest of hatchery turnoff, site C	1997	Jamison	30/50 m ²
Nitinat Main Road, 2 km west of Cowichan Lake	1998	Douglas	8000/5000 m ²
Lake Cowichan/Nitinat–Bamfield road junction, south of	1998	Douglas	2000/7000 m ²
Jasper Creek, unnamed creek SE of	1998	Douglas	100/5000 m ²
Jasper Creek bridge	1998	Douglas	100000+/6 ha
Jasper Creek, 1.9 km NW of	1998	Douglas	50/150 m ²
Klanawa watershed			
W of N Klanawa at confluence	1992	Roemer	unknown
Klanawa River, Moon Creek	1998	Douglas	1/1 m ²
Klanawa River, NE of Corry Creek	1998	Douglas	2/5 m ²
Klanawa River, NE of West Fork of	1998	Douglas	14/10 m ²

Corydalis scouleri is considered by the authors and the British Columbia Conservation Data Centre to be threatened in Canada. Its restricted range and the threat of logging combine to make this species highly vulnerable in the near future.

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Status of the Purple Sanicle, *Sanicula bipinnatifida* (Apiaceae), in Canada†

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Penny, Jenifer L., and George W. Douglas. 2001. Status of Purple Sanicle, *Sanicula bipinnatifida* (Apiaceae), in Canada. *Canadian Field-Naturalist* 115(3): 460–465.

In Canada, there are 21 extant (>1949) populations of *S. bipinnatifida* on southeastern Vancouver Island and the Gulf Islands, 14 of which have been verified in recent years, three of which have been extirpated, and four of which the present status is unknown. There are five historic sites, two of which have been extirpated. These populations represent the northern range limit for the species, which extends south to Baja California in northwestern Mexico. Population sizes range from a single plant to over 1100 plants. The habitat of *S. bipinnatifida* on southeastern Vancouver Island (Garry Oak stands and dry Douglas-fir forests) are rapidly being converted to residential and commercial developments. Although several of the populations receive some protection in parks and ecological reserves, they are still threatened by competition from introduced species. In addition, sites in ecological reserves, regional parks, and municipal parks are at risk due to some management activities and developments. Considering these threats to the habitat of *S. bipinnatifida*, we recommend a status of threatened.

Key Words: Purple Sanicle, *Sanicula bipinnatifida*, threatened, distribution, population size, British Columbia.

Purple Sanicle (*Sanicula bipinnatifida* Douglas ex Hooker) is one of approximately 40 species of *Sanicula* known world-wide (Bell 1954). [Taxonomy and nomenclature follows Douglas et al. (1994, 1998b, 1998c, 1999a, 1999b, 2000, 2001).] The genus is semi-cosmopolitan, well-represented in both the old and the new worlds and mainly found in the north temperate zone. There are five sections in the genus with *S. bipinnatifida* classified in the “Sanicoria” (Shan and Constance 1951). The species in this section exhibit a great variety of developmental trends in their vegetative and reproductive characters. Eight species occur in Canada with five in British Columbia (Scoggan 1979; Douglas et al. 1998b).

Sanicula bipinnatifida is an erect, stout, branching, perennial herb from a vertical, elongated taproot (Figure 1; Hitchcock et al. 1961). It stands 10–60 cm in height with moderately to widely spreading branches that originate from the base. The leaves, which are extremely variable in form, are basal or lower stem, numerous, forming a flat rosette, somewhat thick and leathery in texture, and petiolate, the petioles flattened and usually about as long as the blade. The blades are 4–13 cm long and 3–12 cm wide. The cauline leaves are similar to the basal, but reduced upwards with some subsessile. The range of leaf form variation noted in Bell (1954)

was also observed in the field in British Columbia. Leaves are toothed and once or twice pinnately-divided, sometimes with an obtuse terminal leaflet, or simple. Leaf axes are toothed and winged. The inflorescence is comprised of several to many compact, 3- to 5-radiate umbels. The umbels are 20-flowered with 10–12 staminate flowers and 8–10 perfect flowers. Individual flowers are wine-colored (purple). The involucral bracts are usually two, lanceolate, 0.2–2.5 cm long, foliaceous, and trisect or pinnatifid. The involucels are inconspicuous, composed of six to eight lanceolate, 2.5 mm long bractlets, which are slightly fused at the base with wax-papery margins. The fruits are dry schizocarps (fruits which split into separate carpels at maturity), egg-shaped to sub-globose, 3–6 mm long, and covered with stout, hooked prickles. When this plant is vegetative or fruiting, it may look similar to some Pacific Sanicle (*Sanicula crassicaulis*) plants that have deeply incised to pinnate leaves and reddish flowers.

Distribution

In Canada, *Sanicula bipinnatifida* occurs on southeastern Vancouver Island and the adjacent Gulf Islands (Figure 2; Douglas et al. 1998a). Globally, *S. bipinnatifida* occurs on the west coast of North America from southern British Columbia to northern Baja California, Mexico.

Habitat

Throughout its distribution, *S. bipinnatifida* occurs in several different habitats. In Canada, this

†This report was submitted to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and the species designated Threatened, April 2001.

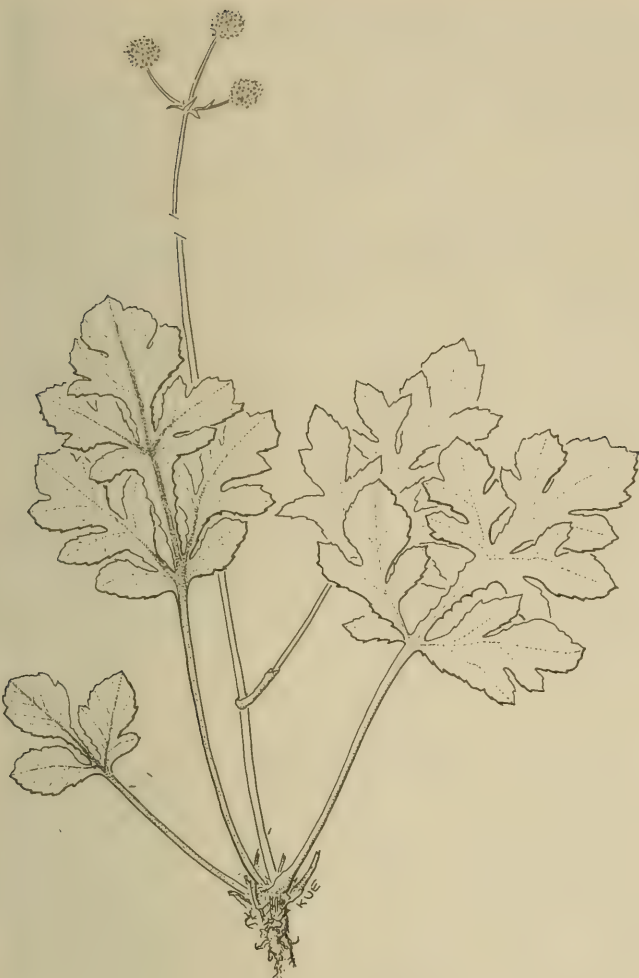


FIGURE 1. Illustration of *Sanicula bipinnatifida* (Line drawing by Karen Uldall-Ekman).

species occurs in the rainshadow of the Coast and Olympic Mountains, in a unique Mediterranean-type climate where dry Douglas-fir (*Pseudotsuga menziesii*) forests and Garry Oak (*Quercus garryana*) stands predominate. *Sanicula bipinnatifida* is relatively shade-intolerant, occurring on very dry to moderately dry, nitrogen-rich, moder or mull humus form soils (Klinka et al. 1989). Early spring conditions are moist, facilitating germination and growth before the onset of summer drought. Specific habitats include grass-forb meadow openings in *Pseudotsuga menziesii*-*Arbutus* (*Arbutus menziesii*) forests, *Quercus garryana*-*Arbutus menziesii* stands, eroding, sandy banks on seashore cliffs, and shrubby, grassy knolls. On southeastern Vancouver Island, *Sanicula bipinnatifida* is mainly a component of the spring flora (April–May), but may persist into late June. Many of the associated species in all sites are introduced.

In one instance, *S. bipinnatifida* was found on a shrubby-grassy knoll dominated by Idaho Fescue (*Festuca idahoensis*), Common Hawthorn (*Crataegus monogyna*), Scotch Broom (*Cytisus scoparius*), and Kentucky Bluegrass (*Poa pratensis*), the latter three of which are introduced.

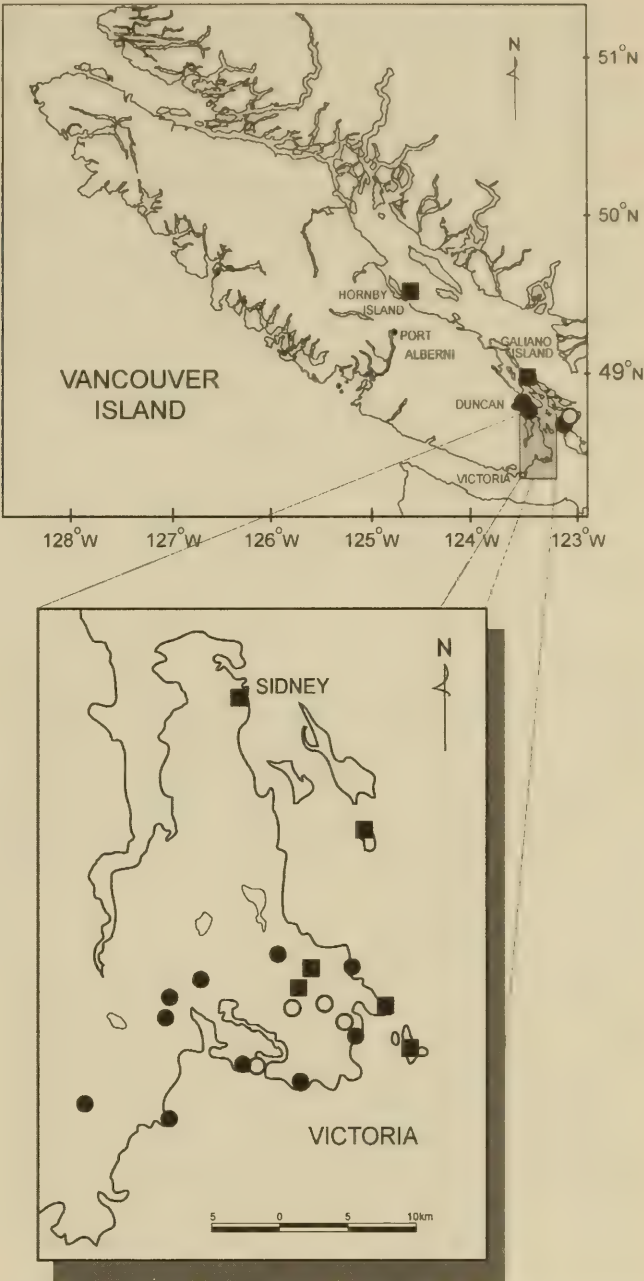


FIGURE 2. Distribution of *Sanicula bipinnatifida* in British Columbia (○ – extirpated sites, ● – recently confirmed sites, ■ – present status unknown).

In the grass-forb meadows, dominants in the month of May include brome (*Bromus* spp.), Sweet Vernal Grass (*Anthoxanthum odoratum*), Long-stoloned Sedge (*Carex inops*), and Many-flowered Woodrush (*Luzula multiflora*).

In the *Quercus garryana*-*Arbutus menziesii* stands, grassy slopes are dominated by Hedgehog Dogtail (*Cynosurus echinatus*), California Oatgrass (*Danthonia californica*), Orchard Grass (*Dactylis glomerata*). Shrubby trailside habitats for *Sanicula bipinnatifida* are dominated by *Cytisus scoparius* and Great Camas (*Camas leitchlinii*).

The eroding sea cliff site at Dallas road is dominated by Beach Pea (*Lathyrus japonicus* var. *maritimus*), Rip-gut Brome (*Bromus rigidus*), Soft Brome (*B.*

hordeaceus), and Kentucky Bluegrass, whereas the Macaulay Point site is dominated by *Sanicula bipinnatifida*, *S. crassicaulis*, Narrow-leaved Plantain (*Plantago lanceolata*) and Perennial Ryegrass (*Lolium perenne*).

A final notable habitat is in the Mount Tzuhalem Ecological Reserve where feral livestock have never grazed and consequently there is a rich diversity of native forbs and grasses. In this site, *Sanicula bipinnatifida* grows on south-facing ledges in a *Quercus garryana* community with Deltoid Balsamroot (*Balsamorhiza deltoidea*), another rare taxon. Spring wildflowers that occur at this site include *Sanicula crassicaulis*, Sierra Sanicle (*S. graveolens*), Henderson's Shootingstar (*Dodecatheon hendersonii*), Spring Gold (*Lomatium utriculatum*), Blue-eyed Mary (*Collinsia parviflora*), Sea Blush (*Plectritis congesta* var. *congesta*) and several others.

Biology

There is little information available on the biology of *Sanicula bipinnatifida* in Canada. This species is briefly mentioned by Shan and Constance (1951) and Bell (1954) in a work on the entire genus of *Sanicula* in the old and the new worlds and a study of variation and polyploidy in the *S. crassicaulis* complex respectively.

Phenology and Growth

Sanicula bipinnatifida is a short-lived perennial. In Canada, it germinates in mesic, but not wet habitats of the early spring season on southeastern Vancouver Island. Flowering occurs by the beginning of May and may continue to the end of June. Experiments conducted by Bell (1954) revealed that germination time for seed planted in the winter or early spring was 41 days. According to Bell (1954), when seed of *S. crassicaulis* and the closely-allied species of it (including *S. bipinnatifida*) germinate, the old seed coats are shed and the small green cotyledons grow rapidly and usually reach their maximum size within a week or 10 days. At this time the true leaf has emerged from the sheath formed by the petioles of the cotyledons. The first year seedling results from the production of seedling leaves, each slightly larger than the last resulting in a loose rosette of small foliage leaves. Growth stops with the beginning of the dry season. Most species in the complex do not flower in the first year, but instead in the second or third year.

Flowers of members of the Apiaceae are fairly unspecialized with little variation from species to species. Pollinators are likely generalist insects. Most species are visited by a large range of pollinators exhibiting little plant-pollinator specificity. The tiny and inconspicuous flowers of *Sanicula bipinnatifida* and others makes them less attractive to pollinators. General floral features of the Apiaceae include: a prominent stylopodium, exposed nectar,

promiscuous (non-specific) pollination, perfect flowers, protandry (male flowers mature before female), regular corollas, sexual reproduction, and semi-compact umbels (Heywood 1971). Within *Sanicula* species there are some exceptions to these general features and some floral specialization. Some of the species including

S. bipinnatifida, are protogynous (female flowers mature before male) rather than protandrous. Furthermore, *Sanicula* species have functional unisexual flowers taking on the role of pistils or stamens. The stylopodium is a structure that is characteristic of the Apiaceae; it is a swollen, often colorful, nectar-secreting style-base which appears to be significant in reproduction. In *Sanicula* species, the stylopodium is somewhat specialized; it is strongly flattened and reduced, thus protecting the nectar. In addition, *Sanicula* species are visited by a relatively high percentage of Hemipterans (True Bugs) which may represent a line of specialization (Heywood 1971).

Population Size and Trends

There are 21 extant (>1949) populations of *S. bipinnatifida* on southeastern Vancouver Island and the Gulf Islands, 14 of which have been verified in recent years, three of which have been extirpated, and four of which with the present status unknown. There are five historic sites, two of which have been extirpated. Population sizes range from a single plant to over eleven hundred plants. The largest population observed occurs at Macaulay Point with approximately 1100 individuals occupying approximately 130 m² (Table 1). Some sites have as few as one to six plants. The historic sites listed are presently areas of heavy urbanization where all native vegetation has been destroyed including *S. bipinnatifida* (Table 1). Only limited information is known for population trends of *S. bipinnatifida*. Populations observed in Metchosin and on Mount Tzuhalem have not changed appreciably over the past five and nineteen years respectively Adolf Ceska, Conservation Data Centre- Conservation Biology Section, Resources Inventory Branch, Ministry of Environmental Lands & Parks, Victoria. (Personal Communication 1999) The junior author has also observed that the population at Cattle Point has remained stable over the last eight years.

Limiting Factors

Sanicula bipinnatifida is mainly limited by human disturbance. There are no apparent biological limitations. Pollination mechanisms are fairly non-specific, and pollinators appear not to be limiting. Fruit dispersal is likely effective due to the numerous prickles found on the schizocarps. Ecologically, populations of this species are somewhat restricted within Canada. Populations only occur on southeastern

TABLE 1. Locations and Population Sizes for *Sanicula bipinnatifida* in British Columbia.

Population	Last observation	Collector	Number of Plants/area
Cedar Hill, Saanich (historic)	1897	Macoun	Extirpated
Cloverdale District, Saanich (historic)	1919	Newcombe	Extirpated
Sidney (historic)	1927	Goddard	Unknown
Blenkinsop road, Saanich (historic)	1939	Unknown	Unknown
Ten Mile Point, Saanich (historic)	1942	Eastham	Unknown
Mount Douglas vicinity, Saanich	1953	Melburn	Unknown
Flora Islet, E of Hornby Island	1976	Pojar	Unknown
Golf Hill, Esquimalt	1976	Ceska	Extirpated
Little D'Arcy Island (S of Sidney Island)	1977	Ceska	Unknown
Alpha Islet, Oak Bay Islands	1981	Ceska	Unknown
Uplands Park, N of Beach Drive, Victoria	1983	van Dieren	Extirpated
East Point, Saturna Island	1984	Janszen	Extirpated
Dionisio Point Park, Galiano Island	1993	Roemer	1/1 m ²
Brown Ridge, Saturna Island	1999	Janszen	140/200 m ²
Mount Tzuhalem Ecological Reserve	1999	Penny & Douglas	94/36 m ²
Uplands Park, Cattle Point, Victoria	1999	Penny & Douglas	215 plants/54 m ²
Metchosin, off Happy Valley road, on Neild road, 2 subpopulations	1999	Penny	446/60 m ² & 184/100 m ² = 630 total
Glencoe Cove Park, Gordon Head	1999	Penny	6/3 m ²
Mill Hill, near summit (3 subpopulations — Calypso trail, Summit trail, and SE slope)	1999	Penny & Fleming	34/24 m ² , 54/72 m ² , & 39/141 m ² = 127 total
Rithet's Bog, strata complex south of bog	1999	Penny & Hartwell	24/4 m ²
Esquimalt, Macaulay Point, E side	1999	Penny	1138/170 m ²
Albert Head, Metchosin	1999	Penny & Donovan	1014/11250 m ²
Mount Tzuhalem (Cowichan Bay Indian Reserve 1)	1999	Penny & Douglas	75/16 m ²
Holland Point, Victoria	1999	Penny	63/56 m ²
Francis King Park, SE of	1999	Penny	13/18 m ²
Thetis Lake Regional Park, Seymour Hill	2000	Ussery & Fleming	152/20 m ²

Vancouver Island and in the Gulf Islands in a unique Mediterranean-type climate which is characterized by warm, very dry summers and mild, wet winters.

More important than biological or ecological considerations is the threat of urbanization. Human development has reduced this species historic range and the trend continues in the present day. The most threatened occurrence of *S. bipinnatifida* occurs on private land, on a tract of land southeast of Francis King Park (Table 1). At least one population of rare plants has already been destroyed on this property. In the absence of provincial or good federal endangered species legislation, they will not be required to protect the *Sanicula bipinnatifida* population.

It is likely that *S. bipinnatifida* has been extirpated from five of the sites (Table 1). *Sanicula bipinnatifida* was observed northwest of East Point on Saturna Island in 1984 and has not been seen again (Harvey Janszen, personal communication 1999, Saturna Island, British Columbia). In addition, the senior author and the original collector of the specimen from Golf Hill confirmed that *S. bipinnatifida* has disappeared from the site.

Populations in the municipal and regional parks are likewise not secure. Benches or trails are sometimes constructed over rare plant populations. In the regional parks, there are procedures in place for

determining if rare plants occur in areas slated for alteration via environmental impact assessments. However, this is not true in the municipal parks. One of the municipal park sites contains a very small population of *S. bipinnatifida* (six plants) and the other ones have moderate-sized populations. Populations in ecological reserves could be adversely affected by the activities of groups attempting to manage for introduced species. For instance, during *Cystisus scoparius* removal at Mount Tzuhalem in the past, the exotic plants have been piled up and burned on top of a rare plant population.

In addition, all sites are heavily infested with introduced species, some highly competitive. Many of the dominant grasses in southeastern Vancouver Island communities are exotic. There are also a variety of introduced forbs present as well.

Special Significance of the Taxon

Sanicula bipinnatifida on Vancouver Island and the Gulf Islands may represent genetically distinct individuals because they are the northernmost populations of the species (peripheral populations). Peripheral populations may be regarded as important pools of genetic information, but since they are not globally endangered, there is much less concern for them in terms of conservation. Some empirical evi-

dence exists indicating that isolated peripheral populations are genetically and morphologically distinct from populations in the center of the distribution (Lesica and Allendorf 1995). These populations may serve as a reservoir of genetic material capable of expressing unique adaptations brought on by their peripheral environments that could be of use for future speciation events. For this reason, many authors consider these populations important for the long-term survival and evolution of the species (Mayr 1982; Lesica and Allendorf 1995).

Another consideration of the importance of *S. bipinnatifida* is as a culinary or medicinal herb. All members of the Apiaceae are aromatic plants and include many culinary herbs. Many well-known essential oil constituents were first isolated from members of this family (Heywood 1971). Although not important internationally as food or medicine, the Miwok Indians of the Yosemite area in California used *S. bipinnatifida* as a cure-all by the decoction of root (Barrett and Gifford 1933).

Protection

Sanicula bipinnatifida has been globally ranked by The Nature Conservancy of the United States as "G5," or "common to very common with an existence that has been demonstrated to be secure and essentially ineradicable under present conditions."

The British Columbia Conservation Data Centre considers *S. bipinnatifida* a Ministry of Environment "Red-listed," or a threatened/endangered taxon (Douglas et al. 1998a). This taxon is ranked as an "S2," in British Columbia, or "critically imperilled because of rarity (typically 6–20 extant occurrences or few remaining individuals) or because of some factor(s) making it vulnerable to extirpation or extinction." *Sanicula bipinnatifida* has a national rank in Canada of N2.

There is no legislation that protects *S. bipinnatifida* in British Columbia and the up-coming federal endangered species legislation will only provide protection for plants on federal lands that are listed by the federal government. Currently, *S. bipinnatifida* is not listed and occurs on federal land in only two sites.

Evaluation of Status

Sanicula bipinnatifida has a restricted range in Canada, occurring only on southeastern Vancouver Island and the Gulf Islands. The 14 recently confirmed populations fall within relatively rare ecosystems for Canada, the dry coastal Douglas-fir forests and the Garry Oak stands. Most of the populations face serious long-term threats or consist of only a single or a few individuals. The extensive development that has occurred over the last century within the range of *S. bipinnatifida* leaves little undisturbed habitat left to which it could further spread. In the absence of adequate rare species legislation and

active stewardship, the five populations that occur on private land have an uncertain future. Even in the parks and ecological reserves, rare plant populations are potentially imperilled. Activities such as constructing trails, roads, or boat ramps are always possible threats. For these reasons, the British Columbia Conservation Data Centre and the authors recommend that *Sanicula bipinnatifida* be designated as a threatened taxon in Canada.

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Status of Snake-root Sanicle, *Sanicula arctopoides* (Apiaceae) in Canada†

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Donovan, Marta T., and George W. Douglas. 2001. Status of Snake-root Sanicle, *Sanicula arctopoides* (Apiaceae) in Canada. *Canadian-Field Naturalist* 115(3): 466–471.

In Canada, *Sanicula arctopoides* is restricted to dry rocky outcrop or coastal grassy bluff habitats unique to the Victoria area and adjacent small islands. The species ranges along the coast from central California to its northern limit in British Columbia. Of the twelve sites at which *S. arctopoides* has been collected, the populations at six sites have been confirmed in 1999–2001, whereas the populations at the remaining sites are likely extirpated. Historic records suggest that the taxon has declined in abundance since the early part of the century. Population numbers vary from only fifty plants to in excess of six thousand. Although several populations of *S. arctopoides* are partially protected from direct habitat destruction at sites in which access to the general public is restricted, introduced herbaceous species threaten the continued existence of most populations, especially those that have few plants. The potential for dispersal of this taxon to other sites is limited and opportunities for colonization are constrained by the scarcity of favorable habitats. Accordingly, a status of “endangered” is recommended.

Key Words: Snake-root Sanicle, *Sanicula arctopoides*, endangered, peripheral populations, British Columbia.

Snake-root Sanicle (*Sanicula arctopoides* Hooker & Arnott) [Taxonomy and nomenclature follows Douglas et al 1994, 1998a, 1998b, 1999a, 1999b], is a member of a world-wide genus of about 40 species (Bell 1954). It is one of five species of the genus *Sanicula* occurring in British Columbia (Douglas et al. 1998b) and eight in Canada (Scoggin 1979).

Sanicula arctopoides is a herbaceous taprooted biennial with stems widely branching at the base into prostrate or ascending branches 5–30 cm long (Figure 1; Douglas et al. 1998b). The basal leaves form a rosette, are somewhat succulent and often yellowish-green. The leaves are 3-cleft and irregularly toothed and leaf blades are 2.5–6 cm long and 2.5–9 cm wide. The inflorescence consists of several to many compact umbels, which are borne by a single apical shoot, and develop in the axils of the uppermost rosette leaves. The corollas are bright yellow with a conspicuous involucre that surpasses the flower heads. The flowers of *S. arctopoides* produce seeds in an egg-shaped schizocarp that is 2–5 mm long and covered with stout, hooked prickles.

In the field, *Sanicula arctopoides* may be confused with Purple Sanicle (*S. bipinnatifida*) or Pacific Sanicle (*S. crassicaulis*) both of which may grow

nearby. Both of these plants are distinguished from *S. arctopoides* by an erect growth habit and inconspicuous involucres. *Sanicula bipinnatifida* has a distinctly toothed leaf axis, leaves that are pinnately divided and purple flowers. *Sanicula crassicaulis* has yellow flowers and leaves that are palmately or pinnipalmately divided and tends to grow in more sheltered grassy niches at sites with slightly deeper soils that retain moisture for longer periods of time.

Distribution

Sanicula arctopoides ranges from southeastern Vancouver Island in British Columbia to Santa Barbara County in central California. In Canada, the species occurs in the Victoria area and nearby islands (Figure 2; Douglas et al. 1998a). The nearest known extant occurrence south of Victoria is in Pacific County, southern Washington State (Washington Natural Heritage Program 1999*).

Habitat

The restricted range of *S. arctopoides* in Canada appears to be a result of the distinctive climate found along the coast of southeastern Vancouver Island and the southern Gulf Islands. Limited to low elevations, this unique area is sheltered by the rain shadow of the Vancouver Island and Olympic Mountains and is warmed by air from the Pacific Ocean. The rain shadow effect is responsible for a

†This is a Status Report of a species restricted in Canada to British Columbia. This report was submitted to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and in April 2001 the species was designated “Endangered”.

*See Documents Cited section.



FIGURE 1. Illustration of *Sanicula arctopoides*. (Line drawing by Karen Uldal-Eckman)

Mediterranean climate that differs markedly from the rest of the province, contributing to the area's warm, dry summers and mild, wet winters. The dominant forest vegetation in this region is Douglas-fir (*Pseudotsuga menziesii*), a fire-climax species that occurs in a wide range of sites from rocky outcrops to moist valley bottoms. In areas characterised by low rainfall, shallow soils and rock outcrops, Garry Oaks (*Quercus garryana*) form open stands of trees mixed with grass-dominated meadows. In addition to *S. arctopoides*, the rock outcrop and vernal seep habitats found within the rain shadow zone favour the growth of many other rare plants which are also at the northern limit of their distribution.

Sanicula arctopoides occurs on low, dry, grassy coastal bluffs along the shoreline in the Victoria area. All sites are in vernal seeps on gravelly or rocky outcrops near the ocean where the plants are exposed to salt spray, sun and wind. Growing in shallow soils over bedrock, the plants have a low cushion form that provides protection from wind and desiccation and concentrates solar energy at soil level, warming the roots.

Trial Island Ecological Reserve supports the largest and most vigorous extant population of *S. arctopoides*. The plants grow on open, west facing, grassy banks close to the shore and on rocky moss ledges with spring seepage. The population is part of a rich meadow community with Nodding Onion (*Allium cernuum*), Spring Gold (*Lomatium utriculatum*) and Yarrow (*Achillea millefolium*). This site is particularly important in terms of long-term conservation because the habitat is not as fragmented as at other sites and it supports the growth of other rare plant species.

At the Alpha Island Ecological Reserve, *Sanicula arctopoides* is associated with Barestem Desert-parsley (*Lomatium nudicaule*) and Beach Pea (*Lathyrus japonicus*) with Sweet Vernal Grass (*Anthoxanthum odoratum*), Red Fescue (*Festuca rubra*) and Hairy

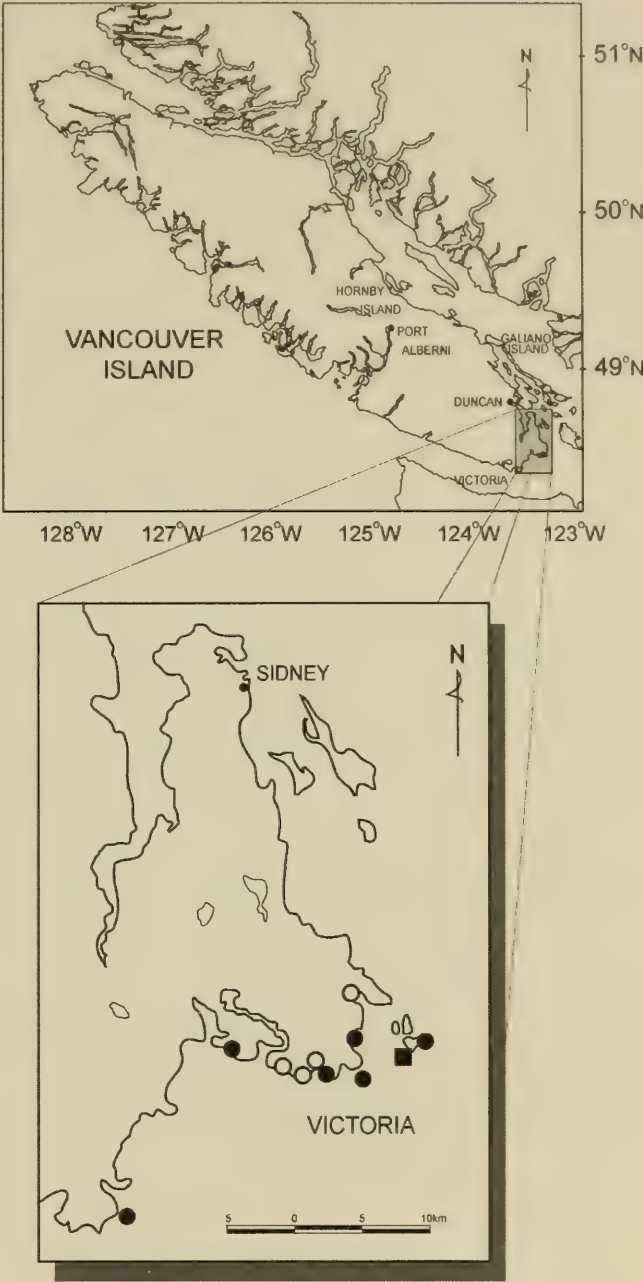


FIGURE 2. Distribution of *Sanicula arctopoides* in British Columbia (○ – extirpated sites, ● – recently confirmed sites, ■ – present status unknown).

Cat's-ear (*Hypochaeris radicata*). Although the overall site quality is fair to good, introduced species appeared to be more abundant here than at the Trial Islands Ecological Reserve.

The population of *S. arctopoides* at Saxe Point Park is located on a gently sloping south facing grassy bluff in shallow soil over bedrock with Thrift (*Armeria maritima*), *Sanicula crassicaulis*, and Common Camas (*Camassia quamash*). Seaside Plantain (*Plantago maritima*) and *Cytisus scoparius* were also observed at this site.

Two small populations of *S. arctopoides* were observed at Bentinck Island on a grassy bluff above a rocky shore. The first population, located on the southwest side of the island was dominated by Early

Hairgrass (*Aira praecox*), Idaho Fescue (*Festuca idahoensis*), Soft Brome (*Bromus hordeaceus*) and Barren Fescue (*Vulpia bromioides*). Common Velvetgrass (*Holcus lanatus*), *Hypochaeris radicata* and Garden Sorrel (*Rumex acetosella*) were also present. The second, larger population at the southern tip of the unnamed point that is located west of George Point, was associated with *Aira praecox*, *Festuca rubra*, *Festuca rubra*, Small-flowered Birds-foot Trefoil (*Lotus micranthus*), *Armeria maritima*, Sand Clover (*Trifolium willdenowii*), *Cladina* and other lichen species.

The small population of *S. arctopoides* at Harling Point is located along a footpath within a few metres of the ocean bluff. The habitat at this location is the most degraded of all the sites. Dominant species include the introduced grasses: Rip-gut Brome (*Bromus rigidus*), Perennial Ryegrass (*Lolium perenne*) and *Dactylis glomerata*. Native species present included Entire-leaved Gumweed (*Grindelia integrifolia*) and Hooker's Onion (*Allium acuminatum*).

At Mary Tod Islet, two small populations of approximately one hundred mature plants and another hundred seedlings were found in a dry grassy meadow dominated by *Aira praecox*, *Bromus rigidus*, Hedgehog Dogtail (*Cynosurus echinatus*) and *Holcus lanatus*. *Lomatium nudicaule* and Two-coloured Lupine (*Lupinus bicolor*) were also present.

Biology

Sanicula arctopoides is a biennial, that flowers during a single season, in March and April of its second year. Umbels are produced in a hierarchical pattern and may be divided into ranks or orders based on their spatial location on the flowering stalk and the timing of flowering. Umbel orders mature in 9–18 day intervals and each order develops in the axils of leafy bracts subtending the previously formed order. Secondary umbels are axillary to the single apical primary umbel, tertiary umbels are axillary to the secondary umbels and, if present, quaternary umbels are axillary to the tertiary ones. Each umbel bears a mixture of bisexual and staminate flowers. The single apical primary umbel is composed almost entirely of staminate flowers.

No information is available on the biology and ecology of *S. arctopoides* in British Columbia. Therefore it is not possible to compare British Columbia populations with those found in the main range of the species in Oregon and California.

There has been some research conducted on populations of *S. arctopoides* in California where the plant is more common. Lowenberg (1994) published the results of a study into the effects of floral herbivory on maternal reproduction in natural populations of *S. arctopoides*. The removal of inflorescences, both naturally by grazing Black-tailed Deer (*Odocoileus hemionus* Rafinesque ssp. *columbianus* Richardson)

and by artificial clipping early in the flowering season, resulted in no loss of maternal reproduction as measured by seed number and seed mass.

Lowenberg (1994) found that when primary and secondary umbels bearing up to one-third of a plant's flowers were removed at the stage when plants are normally grazed, full compensation for seed number occurred. There are, however, thresholds both in timing and in severity of removal beyond which plants were unable to compensate fully. It is possible that an herbivore-induced change in allocation patterns is the most likely mechanism for the compensatory response observed, allowing *S. arctopoides* to shift seed production to either earlier or later maturing umbels.

Gender expression in hermaphroditic plant species is often affected by a variety of environmental factors, which may include herbivory. Although the effects of herbivory on gender display have not been well documented, several studies have demonstrated that herbivory may reverse or reduce the tendency of unmanipulated plants to produce a greater proportion of staminate (male) flowers as the flowering season progresses.

Working with andromonoecious dicots, Hendrix and Trapp (1981), Hendrix (1984) and May and Spears (1988) reported that the destruction of ovaries in bisexual flowers led to increased bisexual flower production later in the reproductive season. Similarly, the results of a study by Diggle (1993) indicated that lack of pollination in the andromonoecious annual, *Solanum hirtum*, produced more bisexual and almost no staminate flowers throughout the course of the flowering season. In each of these studies, the flowers of plants undamaged by herbivory and those that were heavily pollinated typically become increasingly male as the flowering season progresses.

Unlike the andromonoecious species cited above, in *Sanicula arctopoides*, the proportion of staminate flowers on later umbels declines as the season progresses. Lowenberg (1997) assessed the role of both herbivory and lack of pollination in determining the proportion of staminate and hermaphroditic flowers in *S. arctopoides*. Although neither factor appeared to affect gender expression to any significant degree, the probability of producing staminate flowers on later umbels was positively related to plant size, or, more specifically to rosette area. It was suggested that staminate flowers on late umbels may be of greater benefit to large early-blooming plants than to small late blooming plants because more mating opportunities exist when these flowers release their pollen.

Population Number, Sizes and Trends

There are twelve reported locations of *S. arctopoides* in the Victoria area (Table 1). Of the twelve

reported locations, only six sites could be verified during this study. Populations range from fifty to over six thousand individuals. The largest population observed to date occurs on Trial Island (Table 1).

Sanicula arctopoides has been recorded in the Victoria area since 1897. Records at the British Columbia Conservation Data Centre report that it occurred historically in Victoria at Clover Point, at Cadboro Bay, at Foul Bay, on the edge of cliffs at Beacon Hill Park, and on the waterfront at the foot of Menzies Street. Although *S. arctopoides* may once have occurred at each of these sites, all have been extensively disturbed and no populations have been verified in recent years. They have probably been extirpated. Two other historic records are unmappable because the locality is too vague (i.e., Victoria).

Although there have been no long-term studies of the population dynamics of *S. arctopoides* in the Victoria area, the population numbers at Trial Island and Harling Point have been relatively stable since 1992 and 1977, respectively.

Limiting Factors

The primary and most immediate threat to *Sanicula arctopoides* in British Columbia is the loss and degradation of waterfront habitat on both public and private property in the Greater Victoria region. All extant populations occur in small, isolated fragments of rocky outcrop and grassy meadow habitats. The species is also threatened by the cultivation of non-native plants and competition from aggressive introduced species. Lawn grasses and ornamental horticultural plants have often been planted in parks where suitable habitat for *S. arctopoides* may once have existed. Human manipulation of moisture regimes through landscaping practices may also have contributed to the disappearance of *S. arctopoides* in suitable habitats. The rapid pace of land transformation in the Victoria area may have also resulted in barriers to seed dispersal.

The most secure populations of *S. arctopoides*

occur in protected Ecological Reserves and on Department of National Defense (DND) property where access by the general public is restricted.

Saxe Point Park is a popular and frequently visited Municipal Park located along the waterfront in Esquimalt. Although the populations of *S. arctopoides* in the park are in an area of relatively heavy pedestrian traffic, they appear not to be threatened by park visitors at the present time. Although the site is subject to some trampling, this activity may, in fact, serve to reduce competition from introduced grass species. However, the population at this site could be at risk if park development, such as trail or bench construction, is scheduled in the future.

The outlook for the small population at Harling Point appears to be the most precarious. Although the property is presently a privately owned cemetery, there is no assurance of protection for this oceanfront site from development in the future. Once a population becomes small because of habitat fragmentation, it becomes more vulnerable to demographic and environmental variation and loss of genetic variability. In some cases, small populations are at risk of inbreeding depression, genetic drift and loss of fitness (Primack 1998).

Populations of aggressive weedy exotics such as *Cytisus scoparius*, *Dactylis glomerata* and *Bromus sterilis* have become established at all sites and threaten the long-term ecological integrity of each population. The naturally open structure of rocky outcrops and grassy bluffs has likely contributed to these habitats being somewhat predisposed to weed invasion, especially where the soil is disturbed. These invasive species have altered the composition and structure of large areas of the Garry Oak (*Quercus garryana*) landscape on southeastern Vancouver Island and in some areas have completely replaced the native vegetation.

Special Significance of the Taxon

The rock outcrop and vernal seep habitats on southeastern Vancouver Island are especially signifi-

TABLE 1. Locations and population sizes for *S. arctopoides* in the Victoria area, British Columbia.

Collection site	Last observation	Collector	Number of plants/area
Chain Island (Victoria)	1897	J. R. Anderson	unknown
Cadboro Bay (Victoria)	1913	W. Taylor	extirpated
Clover Point (Victoria)	1913	J. Macoun	extirpated
Menzies Street (Victoria)	1917	C. F. Newcombe	extirpated
Beacon Hill Park (Victoria)	1938	J. W. Eastham	extirpated
Foul Bay (Victoria)	1942	G. A. Hardy	extirpated
Alpha Islet Ecological Reserve	1999	M. Donovan & G. Douglas	52/52 m ²
Bentinck Island, Rocky Point (Victoria)	1999	M. Donovan & J. Penny	71/21 m ²
Harling Point, Chinese Cemetery (Victoria)	1999	M. Donovan & G. Douglas	81/250 m ²
Saxe Point Park (Victoria)	1999	M. Donovan	1145/215 m ²
Trial Island Ecological Reserve (Victoria)	1999	M. Donovan & J. Penny	6015/3076 m ²
Mary Tod Islet	2001	M. Donovan & G. Douglas	100/150 m ²

cant because they support the growth of a number of plants, in addition to *S. arctopoides*, that are rare in British Columbia. Efforts to protect rare species associated with this unique ecosystem may, in turn, help to protect many other native species associated with this particular habitat.

As peripheral populations at the northern extent of their geographic range, these taxa present an interesting dilemma. On the one hand, taxa that are not globally endangered can be viewed as being of lesser conservation significance than those which are globally endangered. However, isolated peripheral populations are often genetically and morphologically divergent from central populations and may have an evolutionary and ecological significance out of proportion to the percentage of the species they represent (Mayr 1982; Lesica and Allendorf 1995). The protection of genetically distinct peripheral populations may be important for the long-term survival of the species as a whole (Lesica and Allendorf 1995).

Protection

The British Columbia Conservation Data Centre ranks *S. arctopoides* as an S1 or Red-listed species in British Columbia (Douglas et al. 1998a). This is the most critical rank that can be applied to species at the provincial level and indicates that the species is "critically imperiled because of extreme rarity (typically five or fewer occurrences or very few remaining individuals) or because of some factor(s) making it especially vulnerable to extirpation or extinction". Since the species is restricted to British Columbia it has a national rank in Canada of N1.

Although there is no specific legislation for the protection of rare and endangered vascular plants in British Columbia, the populations at Trial Island and Alpha Islet are located within Ecological Reserves that provide the plants with the greatest degree of legal protection currently available in British Columbia. The populations at Bentinck Island are located on land controlled by the Department of National Defense (DND) where public access is prohibited and, although portions of the island are utilised for training purposes, there are no immediate plans to extend these exercises to the area in which *S. arctopoides* occurs. An Environmental Risk Management Division monitors land use on DND properties but no endangered species legislation exists at the national level in Canada. The population of *S. arctopoides* at Mary Tod Islet is on property that is owned by the Municipality of Oak Bay. No plans for development at this site are known at this time and are considered unlikely in the future.

The Nature Conservancy of the United States has designated a global rank of "G5" for the species, a ranking which indicates that, on a global scale, it is considered to be "common to very common; demon-

strably secure and essentially ineradicable under present conditions". In the southern portion of its range along the central and north coast of California, *S. arctopoides* is common. In Oregon, the plant is not common but is also not considered rare by the Oregon Natural Heritage Program (Scott Sundberg, personal communication 1999, Department of Botany and Plant Pathology, Oregon State University, Corvallis, Oregon). In the state of Washington, where one site remains extant, *S. arctopoides* is ranked S1S2, with a state status indicating that the plant is "Sensitive" (Washington State Natural Heritage Program 1999*).

Evaluation of Status

Sanicula arctopoides is considered an endangered taxon in Canada by the authors and the British Columbia Conservation Data Centre. Suitable habitats for *Sanicula arctopoides* are rare in Canada and are restricted to the Victoria area and adjacent local islands. The potential for dispersal and opportunities for colonisation are extremely limited.

Only six extant populations are known in British Columbia. The existence of populations at risk depends on the protection of the marginal habitats in which they occur. In the absence of federal or provincial rare species legislation or active stewardship, populations of rare plants on private lands are much less secure than those in protected areas. Although three of the extant populations are protected in Ecological Reserves, an increasing abundance of aggressive introduced species at these sites may threaten the survival of *S. arctopoides* in the future. The populations at Trial Island and Alpha Islet are also at risk from potential oil spills since they are alongside one of the most active oil shipping lanes in North America.

Populations of *S. arctopoides* in British Columbia are at the northern extent of their range and may represent populations that are genetically distinct and important for the long-term survival and evolution of the species. The exclusion of *S. arctopoides* and other peripheral species at the geographic margins of their range from legal protection could result in a significant and irreversible loss of Canada's genetic resources.

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Spatial Scales of Trapping in Small-mammal Research

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We surveyed 127 published small-mammal trapping studies (of either *Peromyscus maniculatus* or *Clethrionomys gapperi*) to assess the range of sizes used in the design of trap arrays. The distribution of trap spacings was bimodal, with peaks at 10 and 15 m. The mean extent of trapping arrays was 1.8 ha for grids and 358 m for transects. Only seven manuscripts mentioned prebaiting. The results suggest that many small-mammal studies are designed in a similar way, at small spatial scales. Larger-scale patterns and processes may occur undetected without larger-scale sampling designs. We present and discuss some recent examples from the literature.

Key Words: *Clethrionomys*, dispersal, landscape context, *Peromyscus*, prebaiting, sampling, scale, small mammal, spatial autocorrelation, synchrony, trapping, winter mortality.

Ecological research has often been carried out over a narrow range of relatively small spatial scales (Kareiva and Anderson 1989; Brown and Roughgarden 1990). This broad observation also may apply to small-mammal research. One consequence of working at small spatial scales is that larger-scale patterns and processes can be overlooked or misinterpreted (Wiens et al. 1993). For example, Wegner and Merriam (1990) showed that White-footed Mice, *Peromyscus leucopus*, use agricultural fields adjacent to forest fragments; a phenomenon that could have been overlooked without considering landscape context. Empirical small-mammal field studies commonly employ grid or transect arrays of traps, the design of which often establishes the spatial scale of the study. We surveyed the literature to assess the range of trapping array sizes, and thus spatial scales, used in small-mammal research.

Methods

We surveyed 127 studies published in five journals (*American Midland Naturalist*, *The Canadian Field-Naturalist*, *Canadian Journal of Zoology*, *Ecology*, and *Journal of Mammalogy*) between 1960 and 1998. We selected only field-based studies of two common species: the Red-backed Vole, *Clethrionomys gapperi*, and the Deer Mouse, *Peromyscus maniculatus*. From each published manuscript, we tabulated information on trap spacing, spatial extent of grid or transect, total trap nights of the study, length of trapping period, length of prebait period, and the number of grid or transect replicates. Replication was a difficult issue to evaluate as authors often did not clearly discuss assumptions about the spatial independence of sampling sites.

Grids or transects were assumed to be replicated if multiple sites were sampled within a single study, whether or not these sites were truly independent in the statistical sense. This included the few studies where large-scale questions were addressed by the spatially-explicit juxtaposition of small replicates (e.g., Morris 1996). Areal units were converted to ha and length was converted to m. Some authors published multiple manuscripts from one field study, and in these cases we only included one sample. When multiple designs (e.g., transect and grid) were used in one study they were considered as separate samples. We carried out an exploratory analysis of the tabulated data.

Results and Discussion

The majority of studies in our survey (N = 80; Table 1) employed trapping grids rather than transects. The mean extent of the grids was 1.8 ha while the mean extent of transects was 358 m (Figure 1; Table 1). More than 50% of transects were < 300 m, and more than 50% of grids were 1 ha or smaller (Figure 1).

Although the mean trap spacing was 14 m, the distribution of spacings was bimodal, with peaks at 10 and 15 m (Figure 2; Table 1). The convention of using 10- or 15-m trap spacing seems to be based in part on papers by Burt (1940), Calhoun (1948), Kikkawa (1964) and Smith et al. (1975). Calhoun (1948) presented a standardized protocol for the "North American Census of Small Mammals", which used trap stations spaced 20, 50, or 100 ft apart. Note that 50 ft is approximately 15 m. Kikkawa (1964) suggested a 10-m spacing in a deciduous woodland, while Smith et al. (1975) indicated that 15 m is a good

TABLE 1. Descriptive statistics of small-mammal trapping designs published between 1960 and 1998 in five journals*.

Variable	N	Mean	Median	SE	Min	Max
Trap spacing (m)	114	14	15	0.6	2	45
Extent (grid; ha)	80	1.8	1.0	0.3	< 0.1	18
Extent (transect; m)	30	358	294	55.3	16	1309
Number of replicates	116	24	6	4.6	1	429
Length of trapping period (# nights)	68	4	3	0.3	2	14
Length of prebait period (# nights)	121	0.1	0.0	< 0.1	0	5
Total trap nights	112	11238	5346	1403	154	90000

*Field studies of *Peromyscus maniculatus* and/or *Clethrionomys gapperi* published in *American Midland Naturalist*, *Canadian Field-Naturalist*, *Canadian Journal of Zoology*, *Ecology*, or *Journal of Mammalogy*.

compromise distance for studying a range of species. However, we agree with Tew et al. (1994) that there should be no a priori standard distance between traps.

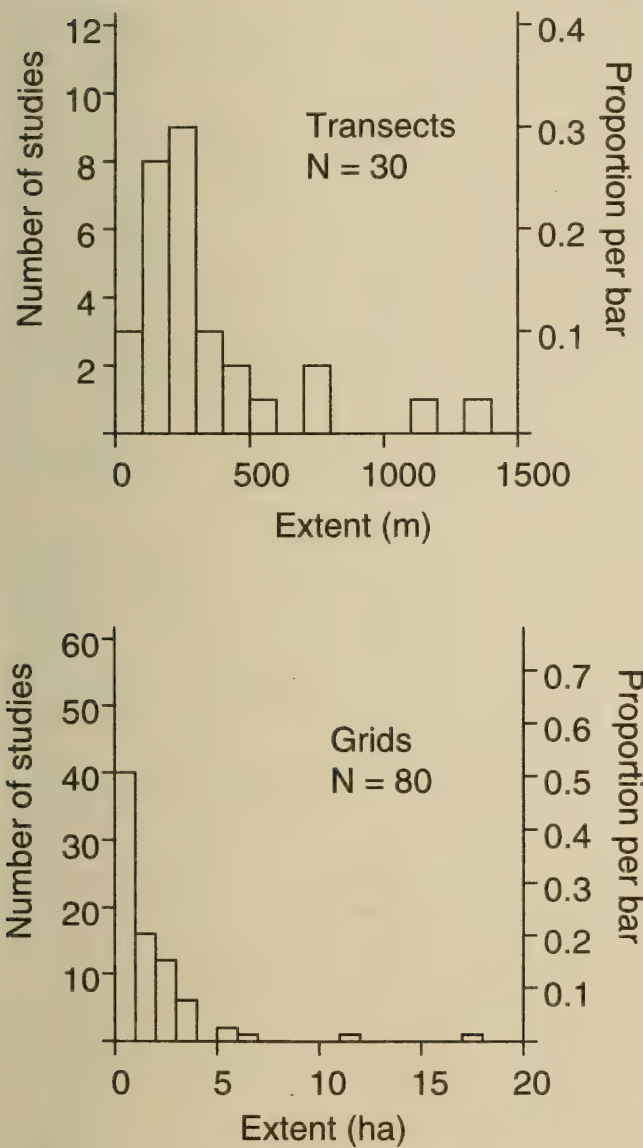


Figure 1. Spatial extent of trapping arrays used in studies of *Clethrionomys gapperi* and/or *Peromyscus maniculatus* published in five journals (*American Midland Naturalist*, *Canadian Field-Naturalist*, *Canadian Journal of Zoology*, *Ecology*, and *Journal of Mammalogy*) between 1960 and 1998.

The selection of a trap spacing should be based on the question of interest and on the site-specific biology of the study species. For example, a spacing might be selected so that each individual has a trap within its home range. This is balanced against the extent of the trapping design and the number of traps logistically feasible. In practice, the extent of the trapping unit (grid or transect) and the spacing of traps are chosen as a compromise between wanting a large area covered in traps and wanting adequate coverage of that area. For example, Tew et al. (1994) demonstrated that a 10-ha grid with a 24-m spacing was an efficient way to sample a low density, widely dispersed Wood Mouse (*Apodemus sylvaticus*) population. We were surprised at how rarely prebaiting has been practised by small-mammal researchers. Only 7 of 127 studies indicated that traps were prebaited. Other authors either did not mention prebaiting or specifically indicated that it did not take place.

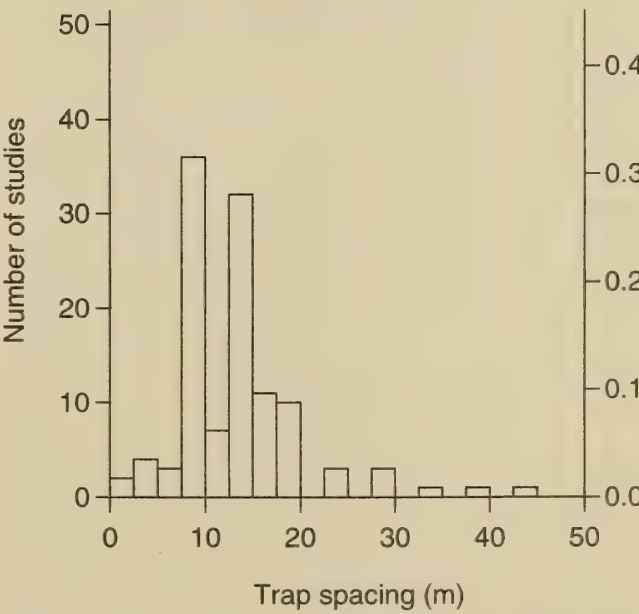


Figure 2. Trap spacing used in studies of *Clethrionomys gapperi* and/or *Peromyscus maniculatus* published in five journals (*American Midland Naturalist*, *Canadian Field-Naturalist*, *Canadian Journal of Zoology*, *Ecology*, and *Journal of Mammalogy*) between 1960 and 1998.

Chitty and Kempson (1949) suggested that prebaiting could be an important method for avoiding the "new object reaction" by rodents. Though there is limited evidence that more animals can be captured during a given trapping period by employing this technique (Chitty and Kempson 1949) it seems that prebaiting is not widely used, or at least not widely reported, in small-mammal studies.

Our survey revealed that between 1960 and 1998 most empirical studies of *C. gapperi* or *P. maniculatus* used similar, small-scale designs. Trapping grids were mostly < 2 ha in extent (or transects < 500 m), and traps were spaced 10- or 15-m apart. Replicate trapping grids often were used (mean number of replicates = 24.0; median = 6; Table 1). These replicates usually were considered to be spatially independent and were used to generate variance estimates. It is apparent that few of the studies in our review have been designed to address questions about large-scale spatial processes. There is, however, a need for such questions since we cannot assume that population processes are restricted to small areas.

This last point has been empirically demonstrated in recent years, by the few studies that have been designed to look at large-scale spatial processes in small-mammal populations. For example, Morris (1992) and Knight and Morris (1996) have used the spatially-explicit juxtaposition of small, replicate trapping grids to measure density-dependent habitat selection. This approach is different from many others in that the replicate grids are not considered as independent samples. Rather, their juxtaposition in space is used to measure spatial processes. Bowman et al. (2001a,b) also used explicitly juxtaposed replicates. They have demonstrated dynamic temporal and spatial structure in *Clethrionomys* and *Peromyscus* populations over a spatial scale that corresponds to dispersal distance and they have hypothesized that winter extinctions and spring recolonizations play an important role in the spatial dynamics of these populations. Finally, a number of authors have used very large, spatially-explicit grid or transect designs to measure regional synchrony in small-mammal population dynamics (e.g., Steen et al. 1996; Bjornstad et al. 1999; Mackinnon et al. 2001).

A common feature of these recent studies is that they use sampling designs that measure space over relatively large areas as a surrogate for spatial population processes. This is either done by using a systematic design that controls the distance between replicates (e.g., Morris 1992) or by varying the spatial extent of environmental samples taken around replicates (e.g., calculating landscape metrics over buffers of varying radii; Bowman et al. 2001c). A major challenge currently facing small-mammal ecologists is to link these relatively large-scale processes with the kind of well-studied, local popula-

tion dynamics that have long been sampled using the traditional methods described in our literature review.

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Diets of Nesting Boreal Owls, *Aegolius funereus*, in Western Interior Alaska

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Boreal Owls, *Aegolius funereus*, a circumboreal species, are relatively common throughout interior Alaska where suitable habitat exists. Although research has been conducted on the conspecific Tengmalm's Owl in Eurasia, little is known concerning their requirements in North America, especially in Alaska. Along with other aspects of Boreal Owl ecology, I investigated prey selection and predation rates using nest boxes in western interior Alaska during springs of 1995–1997 based on a total of 778 prey items found in nest boxes. As with studies elsewhere, microtines were the most important dietary component. I hypothesize that plant phenology would influence prey selection during the nesting season because of variations noted in proportions of Northern Red-backed Voles, *Clethrionomys rutilus*, a forest-dwelling species, and Meadow Voles, *Microtus pennsylvanicus*, generally preferring more open areas. From the differences noted in proportions of these two species in the diet, I suspect that Meadow Voles are selected for when grasses and sedges are short. When vegetation growth obscures this prey item, Boreal Owls apparently switch to a higher proportion of Northern Red-backed Voles.

Key Words: *Aegolius funereus*, Alaska, Boreal Owl, *Clethrionomys*, diet, *Microtus*, nest boxes, polygyny.

Boreal Owls (*Aegolius funereus* L.) are listed as common throughout interior Alaska (Armstrong 1980). Few natural nest sites have been documented, although Boreal Owls and the Eurasian conspecific, Tengmalm's Owl, readily use artificial nesting structures (Franz et al. 1984; Sonnerud 1989; Korpimäki 1992). Because of their status as predators at or near the top of the food chain, owls are often viewed as bio-indicators of the health of an ecosystem. In part because the U.S. Forest Service has designated the Boreal Owl as a "sensitive species" requiring special management, basic ecological data are important to collect, analyze, and understand, especially in ecosystems that have not been subjected to man's various modifications. These baseline data are useful for measuring and understanding changes due to habitat alteration or modification.

As part of a larger investigation of Boreal Owl ecology in the Upper Kuskokwim River Basin, Alaska, direct observations of prey items in nest boxes during incubation and brood-rearing periods were used to quantify changes in the nesting-season diet. Other aspects of this investigation will be presented elsewhere (Whitman, in preparation).

Study Area

This study was conducted in western interior Alaska near the village of McGrath (62°55'N, 155°30'W). Elevations ranged from 90 m to 150 m above MSL. Bottomlands associated with the Kuskokwim River floodplain were dominated by White Spruce (*Picea glauca*), Balsam Poplar (*Populus balsamifera*), or Paper Birch (*Betula papyrifera*),

with understories consisting largely of woody shrubs (*Salix alaxensis*, *Vaccinium* spp. and *Alnus crispa*). Poorly drained sites were often dominated by Eastern Larch (*Larix laricina*). Upland sites away from the river were generally Black Spruce (*P. maritima*) with small copses of Quaking Aspen (*Populus tremuloides*) and Paper Birch. Generally, understory vegetation in the upland sites was mat and cushion lichens (largely *Cladonia* spp.) and Red Cranberry (*Vaccinium vitis-idaea*).

Climate in the area was largely continental, with cold winters (mean January temperature –23°C, extremes to –60°C) and moderate summers (mean July temperature +15°C, extremes of +30°C). Mean annual precipitation was 41 cm, most falling as snow. Snow cover at McGrath generally lasts from early October through April, and sometimes accumulates to depths over 125 cm.

Human influence in the area has been light. There were less than 500 residents of McGrath, and no roads access the village. Travel was usually facilitated by small boats or aircraft in the summer. In winter, snowmachines were the primary mode of transportation. Only very light logging has occurred, with most products being firewood and saw lumber for local use.

Methods

In the study area segment where Boreal Owl diets were investigated, 36 artificial nesting boxes, constructed of rough-cut 2.5 cm spruce lumber, were placed in suitable trees near access corridors (along navigable rivers or roadways). In 1995, only one

active site was used for the diet investigation. During both 1996 and 1997, all boxes were visited two or three times early in the incubation period to determine use. In 1996, 14 active nest sites were visited an average of 8.6 times during incubation and brood-rearing periods, for a mean of 3.9 days between visits. In 1997, 14 active nest boxes were visited at a mean rate of 8.2 days between examinations. Access to the boxes was aided by use of an aluminum extension ladder and cordless electric screw-gun for removing and replacing the tops of boxes. Following the nesting season, boxes were cleaned and repaired, and a 5–7 cm layer of clean wood chips was placed in each box for nesting duff.

All prey items were examined to determine species, and feet of rodents and birds were removed with fingernail clippers and discarded to assure against future duplication. Mammal identifications were usually based on gross characteristics, although dental examinations were required on four young specimens. Birds were identified based on feather characters. With the exception of bird and mammal feet, no prey items were removed from the nest boxes. Due to time constraints, no attempt was made to examine prey

remains based on analyses of the detritus “brick” in the floor of nest boxes following fledging.

Changes in proportions of prey items in Boreal Owl diets during the nesting season were based on frequency of occurrence, and were analyzed and presented in 5-day increments. Samples were collected between 11 May–15 June in 1995, and 20 April–5 June during 1996. In 1997, diets were examined only during 20–24 April and 16 May–5 June.

Results

Due to differences in number of active boxes as well as number of nest site visits, we documented 37 individual prey items during 1995, 530 items during 1996, and 201 during 1997. Most prey found in nest boxes was mammalian, comprising 95%, 98% and 96% of the identified prey in 1995, 1996, and 1997, respectively (Table 1). In his summary of Boreal Owl diets, Hayward (1994) indicated a heavy dependence on microtines throughout their North American range where studies have been undertaken. Insects, amphibians, and reptiles were non-existent in the Alaska prey remains, and birds were represented only rarely.

During 1995, the nesting season diet depicted in

TABLE 1. Diet of nesting Boreal Owls (*Aegolius funereus*) in western Interior Alaska during 1995–1997 based on prey items recorded from nest boxes.

			1995		1996		1997	
			no.	%	no.	%	no.	%
MAMMALIA								
Microtidae								
		<i>Clethrionomys rutilus</i>	4	10.8	271	50.2	101	50.2
		<i>Microtus pennsylvanicus</i>	30	81.1	221	40.9	72	35.8
		<i>Microtus xanthognathus</i>			10	1.9	17	8.5
		<i>Lemmus sibiricus</i>			7	1.3		
		Subtotal	34	91.9	509	94.3	190	95.5
Zapodidae								
		<i>Zapus hudsonius</i>	1	1.7	2	0.4		
		Subtotal	1	1.7	2	0.4		
Soricidae								
		<i>Sorex</i> spp.			19	3.5	2	1.0
		Subtotal			19	3.5	2	1.0
Leporidae								
		<i>Lepus americanus</i>					1	0.5
		Subtotal					1	0.5
		TOTAL MAMMALIA	35	94.6	530	98.1	193	96.0
AVES								
	Spruce Grouse	<i>Falciennis canadensis</i>			1	0.2		
	Gray Jay	<i>Perisoreus canadensis</i>			1	0.2	1	0.5
	Boreal Chickadee	<i>Poecile hudsonica</i>			1	0.2	1	0.5
	Swainson's Thrush	<i>Catharus ustulatus</i>			1	0.2		
	Varied Thrush	<i>Ixoreus naevius</i>			1	0.2		
	American Robin	<i>Turdus migratorius</i>			1	0.2		
	Yellow-rumped Warbler	<i>Dendroica coronata</i>	1	2.7	1	0.2		
	White-crowned Warbler	<i>Zonotrichia leucophrys</i>			1	0.2		
	Common Redpoll	<i>Carduelis flammea</i>	1	2.7			6	3.0
	unknown passerine	not identified			2	0.4		
		TOTAL AVES	2	5.4	10	1.9	8	4.0
		GRAND TOTAL	37	100.0	540	100.0	201	100.0

Table 1 was from a single nest box. This box was visited daily from hatching of the first owlet on 11 May until fledging on 15 June. No fresh prey items were found in this box after 28 May, although obviously, the attendant male continued to deliver food to the box. As the dietary needs of the brooding female and her five young were high, prey items were probably consumed soon after the prey was delivered by the male. Although the primary reason for daily nest visits was to gather growth data on the hatchlings (Whitman, in preparation), prey occurrence was recorded. During both 1996 and 1997, diet data were collected from 14 active nest boxes. As with 1995, fresh prey found in boxes during 1996 and 1997 declined during later brooding periods.

When frequency of occurrence of prey items was analyzed by 5-day periods during 1996, incidence of Northern Red-backed Voles (*Clethrionomys rutilus*) was relatively high during early incubation (late April), then declined. During the last half of May and early June, however, their incidence was again quite high (Figure 1). During the late-April through mid-May period when incidence of Northern Red-backed Voles in the diet declined, their occurrence was replaced by a higher incidence of Meadow Voles (*Microtus pennsylvanicus*). Other prey items

made up a relatively small proportion of the diet throughout the nesting period.

Discussion

In North America, data from three investigations indicates that Boreal Owls rely heavily on microtines. In Canada, Bondrup-Nielsen (1978) found 76% of prey items were *Clethrionomys* or *Microtus*. In Colorado, these two genera made up 79% of the diet (Palmer 1986), and in Idaho, Hayward et al. (1993) indicated microtines made up 55% of the prey. Not unlike our observations, birds made up less than 10% of the diet in all previous North American studies.

In western Finland, Korpimäki (1986, 1988) and Korpimäki and Norrdahl (1989) found that *Microtus* and *Clethrionomys* collectively made up 77% of the diet of Tengmalm's Owls. It appears, however, in both North America and Europe, diets become more varied as latitude decreases, probably simply reflecting a greater diversity of available prey (Kloubec and Vacik 1990). Seasonal and annual variations occur as well in Boreal Owl diets (Hayward 1994).

I suspect that Boreal Owls prefer to hunt in small openings in the forest (either natural or man-made) where grasses and sedges are prevalent. In years of late snow cover, April and early May hunting is probably restricted to sloughed river banks, roadways, and

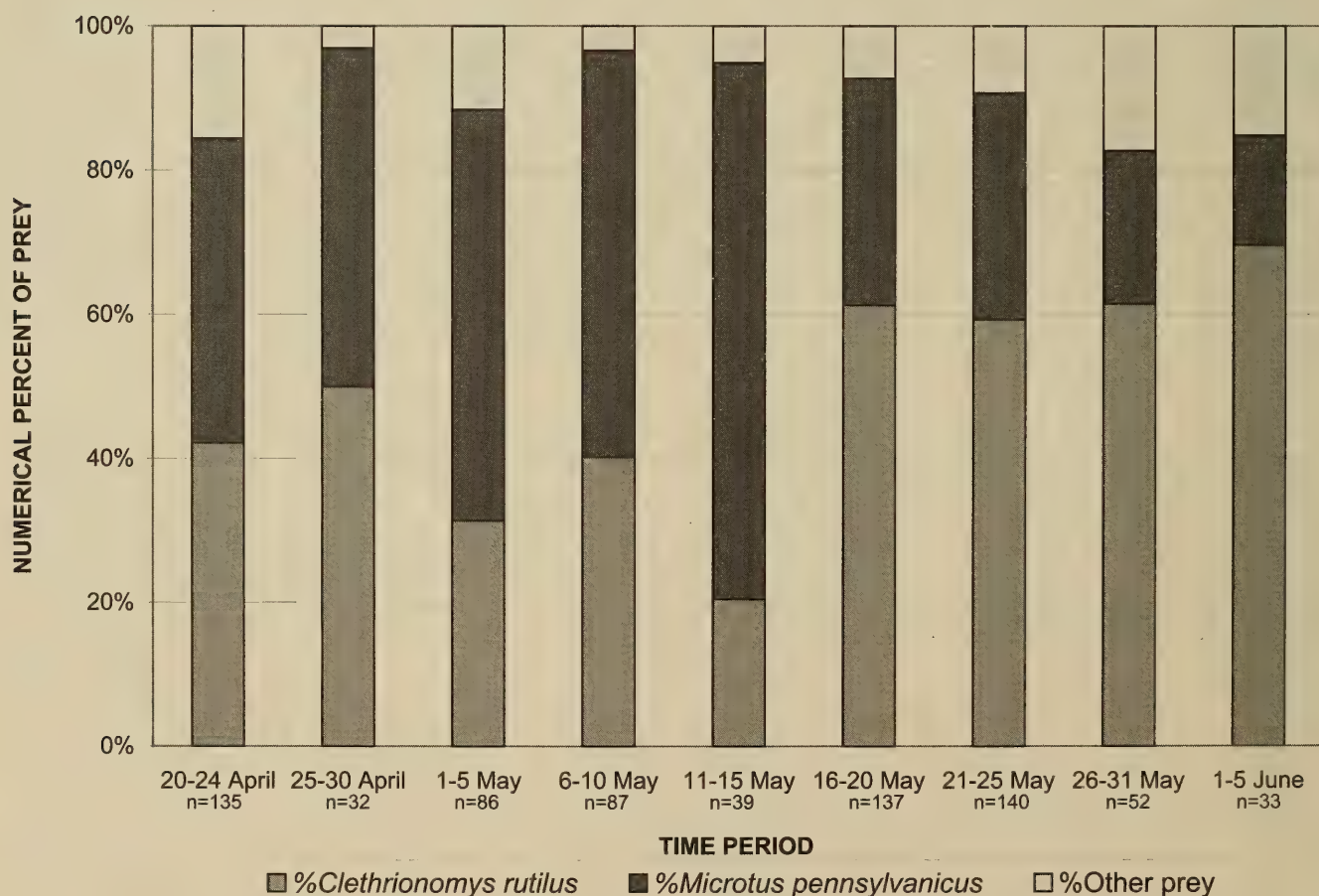


FIGURE 1. Percent frequency of occurrence of major prey items in the diet of nesting Boreal Owls (*Aegolius funereus*) during 5-day intervals during 1995–1997 from western interior Alaska.

small bare patches around the bases of spruce trees. In these situations, Red-backed Voles are probably the predominant prey available. As open meadows become snow-free, these areas appear to be hunted more intensively, as evidenced by the increasing incidence of Meadow Voles as prey items. Then, in late May, as forest environs become devoid of snow (and visibility of Meadow Voles declines) hunting efforts shift back to more heavily forested habitats where understory vegetation is sparse, and Red-backed Voles become the primary target. Amount of snow and plant phenology certainly influences hearing and visibility and thus, hunting success.

Most owl diets are determined from analysis of nesting cavity "bricks" (Ted Swem, personal communication), from observations of foraging owls, or from regurgitated pellets. From these analyses, investigators are able to document a wider variety of prey over a longer period of the year, but it is difficult to document seasonal shifts in prey selection. Therefore, the data herein are helpful in understanding the seasonal importance of micro-habitats for foraging. Small clearings in otherwise monoculture forests (resulting from small-scale clear-cut logging, remote homestead clearing, small wildfires, and rights-of-way, among other things) may be beneficial to Boreal Owls if they result in habitats that become snow-free earlier in the year.

On one occasion during 1997, the rear half of a juvenile Snowshoe Hare (*Lepus americanus*) was found in a nestbox. Another active nest site, about 400 m from the first, held the front half of a hare. Comparison of the halves and the rareness of hares in the diet confirmed it was but one animal. I suspect one male was responsible for maintaining two females with broods at these particular sites, strongly suggesting polygyny. Although most brooding females were captured at the nest boxes and banded, no attempts were made to mark adult males, so confirmation was not possible. In Europe, polygyny has been documented in Tengmalm's Owl (Solheim 1983; Korpimäki 1991), especially during years of high food abundance.

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Influence of Predation on Piping Plover, *Charadrius melodus*, and Least Tern, *Sterna antillarum*, Productivity along the Missouri River in South Dakota

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Predation along the Missouri River in South Dakota was examined from May–August during 1991 and 1992 to determine its influence on Piping Plover (*Charadrius melodus*) and Least Tern (*Sterna antillarum*) productivity. Egested raptor pellet collections, track and trail surveys, time-lapse photography, and visual observations were used to identify predators at active colony sites. Predation was the leading cause of nest and chick loss. American Crow (*Corvus corvus*), Raccoon (*Procyon lotor*), and Mink (*Mustela vison*) caused 98.0% of known nest losses. American Kestrels (*Falco sparverius*) and Great Horned Owls (*Bubo virginianus*) accounted for 93.0% of the documented chick mortalities. Chick escape shelters and wire mesh predator exclosures were evaluated as a means of increasing nest success and chick survival. Piping Plover apparent nest success increased significantly ($P < 0.001$) from 34.4% to 61.6% with the use of predator exclosure cages. Chick shelters were not used by either species and appeared to provide no benefit to chick survival. High predation rates on the Missouri River may be the result of severe habitat deterioration and increased predator effectiveness. Management activities for Piping Plovers and Least Terns should be based on thorough knowledge of predator community composition and dynamics.

Key Words: Piping Plover, *Charadrius melodus*, Least Tern, *Sterna antillarum*, productivity, predation, Missouri River, South Dakota.

Predation is one of several factors that limits the productivity of Great Plains Piping Plovers (*Charadrius melodus*) and interior Least Terns (*Sterna antillarum*) within the Missouri River Basin (Dirks 1990; Higgins and Brashier 1993; Higgins et al. 1999; Mayer and Ryan 1991; USFWS 1991*, 1992*). Changes in land-use practices within the basin have redistributed predator communities and inflated local predator populations (Sargeant et al. 1993). High rates of predation on Piping Plover and Least Tern eggs and chicks within this region are also due to habitat loss as a result of vegetation encroachment (Kruse 1992*), inundation, flow stabilization (Schwalbach 1988), and sandbar degradation (Dirks 1990). Habitat loss concentrates nesting efforts into areas that otherwise would be avoided due to predation (Dolan 1973; Godfrey and Godfrey 1973; Patterson et al. 1991). Concentrating birds on limited habitats may actually attract predators through changes in social interactions (Burger 1984; Hunt et al. 1986; Rodgers 1987). Piping Plovers are territorial nesters (Cairns 1982; Haig and Oring 1988) that depend on cryptic coloration and isolation as defenses against predation (Tinbergen et al. 1966). Piping Plover territorial behavior in limited habitat may increase their sus-

ceptibility to predation through changes in activity patterns caused by intraspecific intolerance, or through changes in nest site selection (Burger 1987).

Several avian [Ring-billed Gulls (*Larus delawarensis*) and California Gulls (*L. californicus*), McCracken et al. 1981; Prindiville-Gaines and Ryan 1988; Northern Harriers (*Circus cyaneus*), Whyte 1985; Great Horned Owls (*Bubo virginianus*), Dirks 1990] and mammalian [Striped Skunks (*Mephitis mephitis*) and Red Fox (*Vulpes vulpes*), Haig and Oring 1988; Mink (*Mustela vison*) and Raccoon (*Procyon lotor*), Dirks 1990] predators may prey on Piping Plover and Least Tern eggs and chicks. However, no research in the Northern Great Plains has identified specific predator species that cause impacts to Piping Plovers and Least Terns, determined timing of the impacts, and evaluated nondestructive methods to reduce predator effectiveness. Our objectives were: (1) to identify predator species having an impact on Piping Plover and Least Tern nest success and chick survival along the Missouri River in South Dakota, and (2) to develop and evaluate techniques to minimize the impacts of predation on Piping Plover and Least Tern nest success and chick recruitment.

Study Area

Our study area was the Fort Randall and Gavins Point reaches of the Missouri River in southeastern South Dakota. The Fort Randall reach (80.5 km) lies between Fort Randall Dam, at Pickstown, South Dakota (43°03'21"N, 98°32'58"W), and Lewis and Clark Lake at Springfield, South Dakota (42°51'09"N, 97°53'25"W). The Gavins Point reach (96.6 km) lies between the Gavins Point Dam at Yankton, South Dakota (42°51'01"N, 97°28'52"W), and Ponca State Park, Dixon County, Nebraska (42°36'03"N, 96°42'36"W). Lewis and Clark Lake, a 22-km artificial impoundment, connects these two reaches. About 98% of the Piping Plovers and 80% of the Least Terns that breed in South Dakota are found on these two river reaches (Schwalbach 1988). Since 1986, annual populations within the study area have averaged 90 pairs of Piping Plovers and 130 pairs of Least Terns (Kruse 1993). Habitat in the study area is characterized by barren to sparsely vegetated inter-channel sandbars. Adjacent landscape consists of a forest corridor (0–850 m) dominated by mature cottonwood trees (*Populus deltoides*). The remaining river floodplain is used for agricultural purposes.

Methods

Productivity Surveys

Piping Plover and Least Tern productivity surveys were conducted from 15 May to 15 August in 1991 and 1992. Methods used for collection of productivity data were those of Schwalbach (1988) and Dirks (1990). Piping Plover and Least Tern nests were found by observing adult birds or by systematic searches of nesting areas. Once found, nests were visited every 5–7 days to determine fate. Nest fate was determined on the basis of nest condition, presence of pipping fragments, egg shells, adult behavior, and presence of chicks (Dirks 1990). Because nests were easily detected and visited frequently, apparent nest success (hatched nests / nest attempts) was used to quantify nest success. Chicks were monitored at 5–7 day intervals until they were lost or became capable of sustained flight (fledged). Because they have high probability of survival, Piping Plover chicks greater than 20 days old and Least Tern chicks greater than 15 days old were counted as fledged (USFWS 1988*). Fledging success was calculated as fledged chicks / breeding pair of adults. The number of adult breeding pairs was determined by the number of nests and an annual adult census conducted during late June.

Predator Surveys

Raptor Pellet Surveys

Regurgitated pellets were used to indicate predation by large raptors (Errington 1930; Craighead and Craighead 1956) on Piping Plovers and Least Terns. Pellets were collected on Piping Plover and Least Tern nesting areas during productivity surveys and from raptor nests adjacent to the river along the

Gavins Point Reach. Efforts focused on large raptors common to the study area, including Great Horned Owls and Red-tailed Hawks (*Buteo jamaicensis*) (Dirks 1990). An aerial survey was conducted on 9 March 1991 to locate potential raptor nests within the floodplain forest corridor. This date corresponded to the initiation of nesting activity by Great Horned Owls in the region (Stewart 1975) and occurred before spring leaf-out of the forest canopy (Gaines and Kohn 1982), maximizing nest visibility from the plane. All potential nest sites were visited during 26–30 April 1991 to determine occupation and remove accumulated pellets prior to arrival of Piping Plovers and Least Terns. Pellets and unconsumed prey parts were subsequently collected within a 10 m diameter circle beneath each active nest every 10 to 14 days until the raptor nest site was vacated. Number of young hatching and surviving to fledge (capable of sustained flight) was recorded for each nest.

Pellets were collected, preserved and dissected according to Korschgen (1980). Skulls, feet, and feathers were used to identify Piping Plovers and Least Terns in pellets. If remains of more than one Piping Plover or Least Tern were identified in a pellet, large bones (e.g., skulls and femurs) were grouped to quantify individuals. Each Piping Plover or Least Tern chick identified from evidence in a pellet was recorded as a take, which we defined as a mortality directly caused by a predator.

Occurrence Surveys

Evidence of predator occurrence on Piping Plover and Least Tern nesting areas was documented during systematic searches conducted concurrently with productivity surveys. Predators observed, track trails (Murie 1974; Rimmer and Deblinger 1990), feces and feathers were used as evidence of predator occurrence. Evidence related to nest, egg, and chick remains that could be attributed to specific predators (Reardon 1951) were recorded as takes. Both complete and partial clutch losses were recorded as single takes. Evidence of occurrence was collected or removed and track trails were mapped to prevent double-counting during subsequent visits. Feces were used to document predator occurrence, but were generally not examined for Piping Plover or Least Tern remains unless a specific take incident was being investigated.

Visual Observation

Visual observation and time-lapse photography were used to document predator activity and its effect on Piping Plover and Least Tern behavior and survival during the peak hatching period (6–13 June). Visual observations of three randomly selected nesting areas were conducted in 1991, with binoculars and spotting scopes from secluded shoreline blinds. Areas were observed during crepuscular and diurnal periods for seven consecutive days. Any takes or interactions between Piping Plovers or Least Terns and predators

were recorded. An interaction was defined as any predator activity causing a behavioral change in Piping Plover or Least Tern incubation, brooding or foraging activity. Minolta XL-401 super-G time-lapse cameras, set at 15-second exposure intervals, were used to record predator occurrence on five additional randomly selected nesting areas. Films were replaced every 24 h for seven consecutive days. Cameras were placed on sandbars with the field of view encompassing the entire nesting area.

Predator Deterrence

Chick Shelters

Chick shelters were placed on sandbars with active nests to provide escape cover for pre-fledged chicks during 1990. Shelters were constructed of wooden snow fence materials (Nan-Jenks 1982), and secured by burying the bottom edge in the sand to the first wire support (10 cm) and staking it through the center. Chick shelters were placed on exposed substrates near chick foraging and loafing areas. Chicks, tracks or feces found inside a shelter during productivity surveys indicated shelter use.

Predator Exclosures

Piping Plover nests were randomly assigned to control (uncaged) or treatment (caged) groups. Exclosures were installed on treatment nests immediately after locating each nest. Predator exclosures, designed for portability and ease of assembly, consisted of 90 × 120 cm top and sides and 90 × 90 cm ends constructed from 5 × 10 cm galvanized weld-wire mesh fencing (Kruse 1993). Exclosures were placed around each treatment nest by pressing them into the sand (2.5 cm) and securing them with wire J-hook stakes (35 cm). Exclosures were observed until an adult entered to attend the nest. If an adult did not enter within 15 minutes, the exclosure was removed. A Wilcoxon signed-ranks test (Wilkinson 1990) was used to test for differences in apparent nesting success between control and treatment nests.

Results

Productivity Surveys

Two hundred fifty-six Piping Plover and 398 Least Tern nests were monitored during 1991 and 1992. Eighteen Piping Plover nests and 44 Least Tern nests with unknown fates were excluded from analysis. Apparent nest success was 46.2% for Piping Plovers and 49.4% for Least Terns (Table 1). Predation was the leading cause of nest loss, accounting for nearly half of all destroyed nests. The remaining nest losses were attributed to inundation, weather events, adult abandonment, human disturbance, and unknown causes. Of 368 Piping Plover and 330 Least Tern chicks that hatched, only 57 plovers and 81 tern chicks survived to fledge (Table 1). Fledge ratios (chicks fledged per pair of breeding adults) were 0.33 for Piping Plovers and 0.32 for Least Terns.

TABLE 1. Productivity summary for Piping Plovers and Least Terns nesting on the Gavins Point and Fort Randall river reaches of the Missouri River, South Dakota, 1991 and 1992.

	Piping Plover	Least Tern
Total Nests	238	354
Total Destroyed	128 (53.8%)	179 (50.6%)
Predation	61 (25.6%)	80 (22.6%)
Chicks Hatched	368	330
Chicks Fledged	57 (15.5%)	81 (24.5%)

Raptor Pellet Surveys

Nineteen potential raptor nest locations were mapped during aerial surveys of the study area. During subsequent field visits we confirmed that five pairs of Great Horned Owls and six pairs of Red-tailed Hawks were occupying nests on the Gavins Point reach. Of these, three Great Horned Owl and five Red-tailed Hawk nests successfully fledged young with a mean productivity rate of 1.2 fledglings per nesting pair for both species. Juvenile Great Horned Owls fledged as early as 16 May and all owl fledglings vacated nests by 29 May. Mean fledge date was 23 May, approximately two weeks before peak hatching (9 June) for Piping Plovers and Least Terns. Red-tailed Hawks had a mean fledge date of 13 July with young fledging from 8 to 19 July, well after the peak hatching period for Piping Plovers and Least Terns.

Forty-one Great Horned Owl and Red-tailed Hawk pellets were collected from the ground beneath nest sites. One (8%) of 13 Great Horned Owl pellets contained remains of an adult Piping Plover with no evidence of any Piping Plover or Least Tern remains in 28 Red-tailed Hawk pellets. Eleven Great Horned Owl pellets were found on sandbars, 9 (82%) of which contained the remains of seven juvenile Piping Plovers and 12 juvenile Least Terns.

Predator Surveys

Ten avian and five mammalian predator species were detected on Piping Plover and Least Tern nesting areas (Table 2). Evidence of 190 occurrences of 11 predator species were noted during weekly productivity surveys, and 13 intrusions of nesting areas by three predator species were photographed during 402 h of time lapse film exposure (Table 2). During 267 h of visual observations, nine species of avian predators were observed 264 times. These avian predators interacted with Piping Plovers and Least Terns 47 times (Table 2). Responses to predator intrusions included vocalized warning calls, aggressive “mob bombing” by terns, and “broken wing” distraction displays and “charge” threats by plovers. Warning vocalizations by adults elicited escape behavior, with chicks either lying still or running to vegetative cover. Great Blue Herons (*Ardea hero-*

TABLE 2. Evidence of predator occurrence, interactions with Piping Plovers and Least Terns, and takes of Piping Plover and Least Tern nests and chicks on nesting colonies on the Gavins Point and Fort Randall river reaches of the Missouri River, South Dakota, 1991 and 1992.

Species	Observation Technique							
	Occurrence Surveys		Visual Observations			Time-lapse Photo	Pellet Analysis	Total
	Occurrence	Takes	Occurrence	Int ^a	Take	Occurrence	Takes	Occurrence Takes
Great Blue Heron	4	0	154	17	0	2		160 0
Great Horned Owl	47	15	12	8	0	9	20	68 35
Ring-billed Gull	0	0	59	5	0	0		59 0
Red-tailed Hawk	30	0	8	1	0	0	0	38 0
American Crow	10	8	9	8	1	0		19 9
American Kestrel	7	1	5	5	3	2		14 4
Caspian Tern	0	0	13	0	0	0		13 0
Bald Eagle	0	0	3	3	0	0		3 0
Golden Eagle ^b	0	0	1	0	0	0		1 0
Northern Harrier	1	0	0	0	0	0		1 0
Raccoon	41	15	0	0	0	0		41 15
Mink	30	22	0	0	0	0		30 22
Domestic Dog	13	1	0	0	0	0		13 1
Coyote ^c	4	0	0	0	0	0		4 0
Striped Skunk	3	0	0	0	0	0		3 0
Total	190	62	264	47	4	13	20	467 86

^aInteractions; ^b*Aquila chrysaetos*; ^c*Canis latrans*

dias), Ring-billed Gulls, and Caspian Terns (*Sterna caspia*) frequented mud flats surrounding the fringes of the nesting areas, but rarely elicited any behavioral changes by Piping Plovers and Least Terns other than vocalizations. In contrast, Great Horned Owls, American Kestrels (*Falco sparverius*), American Crows (*Corvus brachyrhynchos*), and Bald Eagles (*Haliaeetus leucocephalus*) were aggressively approached by adult Piping Plovers and Least Terns when they landed on or near a nesting colony.

During predator surveys, we recorded 66 takes by five species. American Crows (9), Raccoons (15), and Mink (19) caused 43 of 44 (97.7%) documented nest losses. A Domestic Dog (*Canis familiaris*) accounted for one nest take. Mink (3), American Kestrels (4), and Great Horned Owls (15) caused 22 known chick mortalities. An American Kestrel took two chicks from one colony within two hours. This site was completely devoid of Piping Plover and Least Tern chicks seven days later and it was determined that the chicks were too young to have fledged and left the site. In other incidents, a pair of Ring-billed Gulls were observed pursuing 20 day-old Piping Plover chicks, and a brood of 10 to 14 day-old Piping Plovers were observed feeding passively within 2 m of a Great Blue Heron.

Predator Deterrents

Nine chick shelters were placed on seven sandbars during the 1990 nesting season. Only one Piping Plover chick was seen using a shelter. No other evidence of chick shelter use by Piping Plovers or Least

Terns was found. Chicks threatened on shoreline feeding areas or other exposed substrates were observed traveling past shelters to use vegetated areas or driftwood as escape cover.

Apparent nesting success of caged nests (n=86, 62%) was higher ($P < 0.001$) than for control nests (n=122, 34%). Of 33 caged nests that were unsuccessful, 6 (18%) were inundated, 16 (48%) were lost to predation, 2 (6%) were abandoned for unknown reasons, and 9 (27%) were lost due to human disturbance, sandbar erosion, weather, or unknown causes. Of the 16 caged nests that were lost to predators, 11 (69%) were destroyed by Mink, one (6%) by a Domestic Dog, one (6%) by a Raccoon, two (13%) by unknown species, and one (6%) by a Great Horned Owl that struck the side of cage and caused the adult to abandon the nest. Mink predation of caged nests occurred primarily after July. Nests initiated prior to 10 June and protected by cages were more successful (67%) than nests initiated and protected by cages after 10 June (46%).

Piping Plovers readily adapted to predator exclosures, with few behavioral changes noted during post-installation observations. Nesting Piping Plovers with incomplete clutches or nests in early stages of incubation often circled a cage before entering. Adult Piping Plovers with eggs in advanced stages of incubation showed greater nest affinity and did not hesitate to enter a cage. Time between final installation of an exclosure and return of the incubating adult (n=15) ranged from 7 to 195 seconds, and averaged

60 seconds. Piping Plovers left and returned to caged nests by walking or running through openings in the wire mesh; none attempted to exit or enter a cage while flying.

Discussion

We found that predation suppressed Piping Plover and Least Tern productivity along the Gavins Point and Fort Randall reaches. Piping Plover (0.33 chicks/pair) and Least Tern (0.32 chicks/pair) recruitment during our study was below that determined necessary to recover the populations (Piping Plovers 1.44 chicks/pair, Least Terns 0.70 chicks/pair) (USFWS 1990*). We attribute high rates of predation within our study area to habitat changes within the Missouri River Basin (Schwalbach 1988; Kruse 1992*). Although dynamic sandbar complexes are critical to Piping Plover and Least Tern productivity, Missouri River habitat in 1991 and 1992 consisted of small, isolated semi-permanent islands. Because of their longevity, these islands were largely vegetated, limiting available nesting habitat to narrow bands of bare substrate between the water and vegetation. In addition, because of the lack of alternative nesting areas, most nesting areas had also been used for several years prior to our study (Dirks 1990). Under these conditions, predator efficiency was extremely high. When Mink or Raccoons accessed a site, losses were rarely limited to a single nest. Predator efficiency under natural sandbar creation/degradation cycles would likely be lower than those we observed due to the presence of large dynamic sandbar complexes that changed in size, location, and composition annually and the presence of alternative/unused nesting substrates.

Mink, Raccoons, and American Crows were responsible for most of the nest predations we observed. We noted marked changes in the use of nesting areas by these predators throughout the breeding season. Single sets of Mink tracks were often found early in the season (May and June), but were not seen in early and mid-July. In late July, multiple sets of Mink tracks, which we presumed to be family groups, were found on nesting areas. Raccoon tracks, which were common during spring surveys, were rarely found after mid-June. We suggest that these periodic shifts in mammalian predator occurrences are attributable to predator reproductive chronology (young beginning to forage with adults) or the availability of alternative prey. Beginning in mid-July, we observed small groups (<4) of American Crows on nesting areas feeding on common carp (*Cyprinus carpio*) carcasses. We believe American Crows were initially attracted to the sandbars to forage on carp, and we believe any predation of Piping Plover and Least Tern eggs by them during this period was incidental or secondary in purpose.

Predator exclosures enhanced Piping Plover nest-

ing success on the Gavins Point and Fort Randall reaches in 1991 and 1992. In particular, we stress the importance of protecting nests in May and early June, when Mink and Raccoons were most frequently observed on colony sites and overall nest predation rates were highest. While only 19% (16/86) of the caged nests were destroyed by predators, 69% (11) of them were destroyed by Mink. Thus, we urge caution when considering exclosures for areas where Mink are the dominant nest predator, particularly late in the season when Mink are foraging as family groups, and young Mink may be able to enter exclosure cages. Reducing mesh size of the exclosure to 5×5 cm as suggested by Rimmer and Deblinger (1990), may have the potential to deter Mink better. In contrast to reports by Nol and Brooks (1982) and Reynolds (1985), we found no evidence that predators were attracted to nests by exclosures. Although this may become a concern with continued application of this method. Although our exclosures were comparatively small, predators were not able to reach eggs inside of cages. Raccoons reached inside of exclosures on two occasions, but failed to take any eggs there. Other predators deterred by cages included Domestic Dogs, Striped Skunks, and Great Horned Owls.

Great Horned Owls and American Kestrels were the major predators of Piping Plover and Least Tern chicks in 1991 and 1992, and we likely underestimated their effect as evidenced by the number of our unexplained chick disappearances. Except for talon strike marks in the sand, Great Horned Owls left little evidence of a take. Pellet analysis provided the most conclusive evidence of their influence on Piping Plover and Least Tern chicks. Likewise, our only evidence of American Kestrel takes was by direct observation of their predatory events. Chick loss to these avian predators tended to be site-specific and related to the presence of nesting predators along the proximal shoreline. We often saw family groups of fledged Great Horned Owls loafing in the trees along the shore during the day and moving to perches (mostly snags) on colony sites in the evening.

Chick shelters are a non-destructive deterrent technique that has been successfully used on barren Atlantic Coast beaches (Nan-Jenks 1982). In this study, Piping Plover and Least Tern chicks did not use shelters, and we have no evidence they reduced chick loss to predators. With brood rearing habitat in this region of the Missouri River Basin currently containing an abundance of naturally occurring escape cover, we do not recommend providing prefledged chicks with escape structures as a management technique. However, this type of artificial structure should be re-evaluated if natural escape cover is reduced or ephemeral barren sandbars become the dominant habitat type available.

Although various techniques have been developed

to survey predators and to determine predator impacts on wildlife populations (Schemnitz 1980), determining nest and chick losses on our study area was difficult. We believe a combination of monitoring techniques is necessary to provide a complete picture of predator activity and effects. We found that each predator survey technique had its advantages and disadvantages during our study. Although track trail surveys provided evidence of predator occurrence, unstable substrate conditions in our study area (e.g., unconsolidated sand and washover mud) enabled identification of predators from tracks for only short periods of time. Time-lapse photography of entire nesting areas provided limited evidence of predation, targeting specific nests may have provided more information. Although time consuming, field observations of colony sites provided the most quantitative and qualitative data on predation and predator interactions with Piping Plovers and Least Terns. Pellet collection provided the best evidence of chick takes by raptors.

Management Implications

Our results demonstrate the importance of understanding the structure and dynamics of the predator community in making management decisions for Piping Plovers and Least Terns on the Missouri River. We believe the high predation rates we observed were a direct result of sandbar habitat deterioration and the resulting increase in predator foraging efficiency. Thus, we propose habitat improvement as a major management goal to reduce predation and increase productivity of Piping Plovers and Least Terns. Habitat improvements to reduce predator efficiency should include the creation of large, dynamic sandbar complexes that change in size, location, and vegetation composition, as well as the presence of alternate/unused nesting substrates. We also recommend the application of predator deterrents on sites with marginal habitats that receive intense predator pressure. In particular, predator enclosure cages have the potential to increase nest success significantly. Because predator pressure appears to be site specific, application of other predator management techniques (e.g., predator removal, transplant, manipulation of alternative prey resources) to some areas may be justified in specific management situations.

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Population Status of Shorebirds Nesting at Churchill, Manitoba

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Jehl, Joseph R., Jr., and Winli Lin. 2001. Population status of shorebirds nesting at Churchill, Manitoba. *Canadian Field-Naturalist* 115(3): 487–494.

We present a quantitative assessment of shorebird populations breeding in the vicinity of Churchill, Manitoba, in 1997 and compare it with qualitative data amassed since 1930. Our study was based on extensive ground surveys, supplemented by data from long-term studies of several individual species. Over the past seven decades the status of most local shorebirds has changed importantly, and species that were once abundant (Semipalmated Sandpiper, Red-necked Phalarope) have almost vanished. Currently, American Golden-Plover, Whimbrel, Semipalmated Plover, and Dunlin predominate. Future surveys at approximately 10-year intervals are warranted to maintain this exceptional long term record of birdlife in the subarctic.

Key Words: Shorebirds, populations, subarctic, Churchill, Manitoba.

Areas bordering the Hudson Bay coast provide important nesting habitats for a large variety of shorebirds and staging sites for other species migrating to or from more northerly destinations. The Churchill, Manitoba, area (58° N, 94° W) has played an especially prominent role in developing information about shorebird biology because of its easy access and the abundance and diversity of the 15 breeding species, many of which have been studied in some detail locally: American Golden-Plover (Byrkjedal and Thompson 1998; scientific names given in species accounts), Semipalmated Plover (Nol and Blanken 1999), Whimbrel (Skeel 1976, 1983; Lin 1997), Stilt Sandpiper (Jehl 1970; Klima and Jehl 1998), Least Sandpiper (Jehl 1970), Short-billed Dowitcher (Jehl et al. 2001), Hudsonian Godwit (Hagar 1966; Elphick and Klima *in press*), Semipalmated Sandpiper (Gratto-Trevor 1992), Red-necked Phalarope (Reynolds 1987), and Dunlin (Jehl, unpublished).

Churchill's importance became apparent in 1934 with the publication of Taverner and Sutton's classic *The Birds of Churchill, Manitoba*. Over the ensuing seven decades, however, the status of many species changed so greatly that the standard literature (Taverner and Sutton 1934; Jehl and Smith 1970) is out of date. Our goal in this paper is to quantify the numbers of shorebirds breeding in the immediate Churchill area to provide a baseline for further studies. Such information is salient because Churchill has a long ornithological history (Jehl and Smith 1970), is well studied, and is easily accessible, and thus is an important area in which to conduct long term monitoring studies. Shorebirds are important because they are a dominant component of high latitude avifaunas and tend to nest in or near coastal wetlands, the very areas that will be most affected by changes in moisture regimes or sea level that are predicted to accompany global warming.

There has been no previous effort to produce a comprehensive assessment of local shorebird populations, although there are incomplete data for several species (e.g., Skeel 1983; Gratto-Trevor 1993/94). To put our findings in perspective we compared them with estimates of relative abundance provided by, or interpreted from, earlier reports.

Study Area and Methods

In June 1997 we surveyed approximately 7000 ha in the immediate Churchill area for shorebird nests and territories. The study area extended from the coast of Hudson Bay from the southern edge of the Churchill townsite east to Gordon Point, and inland to varying distances south to Landing Lake and the large fen several kilometers north of Twin Lakes [Figure 1A; for detailed maps and place names see Chartier (1994)]. It contains a variety of habitats used by shorebirds including hummock bog, dry and wet sedge meadows, dry and wet tundra, and gravel coastal beaches (and their anthropogenic equivalents — the shoulders of roads and borrow pits).

We divided the study area into five sections:

Section 1: Extends from the southern limits of the townsite to the airport, north to the coast and south to Landing Lake. The habitat between town and the start of Goose Creek Road is primarily well-drained meadow (much modified by humans since 1930), whereas that along the Landing Lake road is wet sedge meadow and hummock-bog.

Section 2: From the dump, north to the coast, east to the Auroral Observatory ("Golfballs"), and south of the Launch Road on the Restricted Access Road to the end of the airport runway. Includes two long-term study plots, one established in 1964 (36 ha), the other in 1992 (40 ha). The habitat is primarily sedge-meadow, with dry areas predominating.

Section 3: From the Auroral Observatory east to

Bird Cove Road, north to the coast and south to Stygge Lake. Includes two plots, one established in 1965 (72 ha), and one in 1993 (40 ha). Habitat along the Launch Road is primarily heath-tundra, rocky ridge and dry plains, with localized patches of wet sedge meadow between the road and Stygge Lake.

Section 4: From Bird Cove Road east to Churchill Northern Studies Centre (CNSC) and Gordon Point, and southward through the Spruce Ridge and Camp Nanuk areas. The habitat is mainly dry tundra with scattered sedge meadow. From about 3 km east of CNSC, we concentrated observations between the coast and 2 km inland, principally along the main tracks leading to Gordon Point but also including all of the two major peninsulas that project into Hudson Bay. Other observations were made along the major trails that lead south onto Christmas Lake Esker.

Section 5: Starts approximately 4 km south of CNSC, extends 1–4 km east and west of the Twin Lakes Road, and continues southward through to the large Twin Lakes fen, which includes a 64-ha plot established in 1992. Habitat east of the road is primarily wet sedge meadow, to the west hummock-bog. Areas of continuous stands of boreal forest were excluded.

Surveys were made by WL and JRJ (occasionally assisted by other biologists) walking approximately 100 m apart on parallel transects through all suitable habitat and recording the presence of territorial birds and nests. Transect data were obtained between 7 and 22 June, by which time local breeders had established territories or were on eggs. For most species the peak of hatching occurred 28 June–5 July (earliest 26 June). Because of the large distances involved,

it was not possible to replicate transects. This was not a problem because in previous seasons (Jehl 1964–1967, 1977, 1991–1996; Lin 1994–1996), we had already amassed detailed information on the distribution and status of shorebirds. This allowed us to concentrate transects work in good habitat and minimize efforts in dry upland areas that support few or no shorebirds. Highly productive areas, however, were visited repeatedly—some almost daily—from early June into mid-July, either because they contained long term census plots or were under special study by us or other researchers.

Results

Of the 15 shorebird species nesting near Churchill, 13 occur in the survey area (Table 1). Two others, Spotted Sandpiper (*Actitis macularia*) and Solitary Sandpiper (*Tringa solitaria*), are rare and nest locally around lakes or in spruce woods farther inland.

American Golden-Plover (*Pluvialis dominica*). Golden-Plovers nest from the south end of the town-site (scarce) and eastward along the coast, and inland to the Twin Lakes fen and about 1 km north of Landing Lake. Most use well drained coastal tundra or dry areas the sedge marshes, although in recent years increasing numbers have been found in wetter situations. The species is conspicuous and territories are easily detected. We found 94 territories, which constitute about 90% of the population to the west and south of CNSC. While our studies to the east were less thorough, shorebirds are so scarce there that we cannot have overlooked any significant number of plovers. We estimated the total population at 110–120 pairs.

TABLE 1. Territorial pairs of shorebirds (and nests) found in Churchill area (see Figure 1) 1997.

Species	Section ¹					Total	Estimated Population ²
	1	2	3	4	5		
American Golden-Plover	25 (5)	9 (1)	10 (1)	40 (30)	10 (6)	94 (43)	110–120
Semipalmated Plover	22 (22)	3 (2)	1 (1)	46 (46)	0 (0)	72 (71)	80
Killdeer	0 (0)	1 (0)	0 (0)	2 (1)	0 (0)	3 (1)	4–5
Lesser Yellowlegs	9 (0)	0 (0)	2 (0)	3 (0)	3 (2)	17 (2)	40
Whimbrel	29 (9)	8 (2)	15 (1)	15 (14)	28 (14)	95 (40)	105–110
Hudsonian Godwit	18 (0)	7 (1)	6 (1)	0 (0)	5 (3)	36 (5)	50–55
Semipalmated Sandpiper	0 (0)	0 (0)	2 (2)	0 (0)	6 (1)	8 (3)	10
Least Sandpiper	8 (6)	7 (3)	10 (4)	3 (1)	8 (3)	36 (17)	80–100
Dunlin	3 (2)	26 (10)	17 (9)	11 (11)	19 (18)	76 (50)	80–100
Stilt Sandpiper	8 (5)	9 (1)	11 (2)	2 (0)	6 (4)	36 (12)	50–60
Short-billed Dowitcher	12 (2)	3 (0)	5 (1)	1 (0)	3 (3)	24 (6)	50–60
Common Snipe	13 (0)	3 (0)	2 (0)	0 (0)	2 (0)	20 (0)	40
Red-necked Phalarope	2 (0)	8 (0)	2 (1)	6 (1)	1 (1)	21 (3)	30–40
Total	149 (51)	84 (20)	83 (23)	129 (104)	91 (55)	538 (253)	719–820

¹For locations of Sections see Figure 1.
²See text for details.

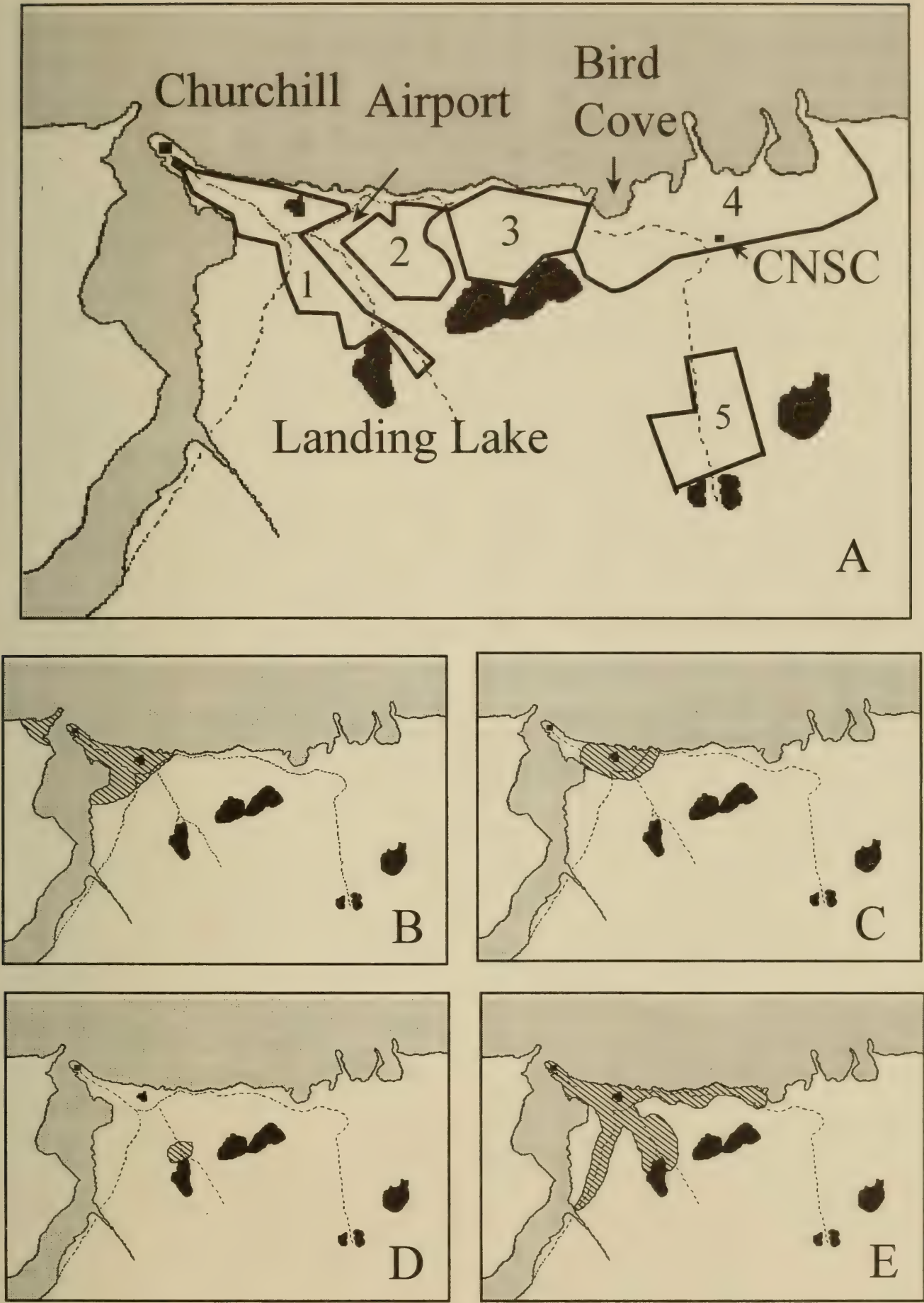


FIGURE 1. A The Churchill, Manitoba, area showing the five areas censused for nesting shorebirds in 1997. Dark areas are lakes. Areas studied (cross-hatched) by earlier investigators: B Taverner and Sutton in 1930–1933, and Grinnell and Palmer in 1940; C Allen in 1944; D Breckenridge et al. in 1954; E Jehl in 1964–1967.

Semipalmated Plover (*Charadrius semipalmatus*). This conspicuous species nests almost exclusively in very dry habitats, typically coastal beaches and adjacent lichen tundra, and occasionally the gravel shoulders of roads. Studies from 1988 through 1996 emphasizing coastal sites indicated a population of 45–55 pairs (E. Nol, personal communication). Our broader surveys detected 72 territories and 71 nests, the majority on the beaches in the eastern part of Section 1 (mainly the gravel extraction plant below old Fort Churchill) and in Section 4 (Halfway Point). Very few birds (< than 3% of the population) breed inland (E. Nol, personal communication). We estimated about 80 pairs in the survey area. A few others nest in the townsite and along the flats of the Churchill River.

Killdeer (*Charadrius vociferus*). We found three territories, including one nest. Other studies (1991–1998) indicated that the local population averages 4–5 pairs (up to 6–8 pairs in some years; E. Nol, personal communication). Killdeers nested usually in disturbed situations (e.g., roadsides, dumps), occasionally on undisturbed tundra. An additional 1–2 pairs nested in the townsite (not surveyed).

Lesser Yellowlegs (*Tringa flavipes*). Yellowlegs are fairly common in brushy or forested areas, but only rarely breed in the open habitats we studied. Most territories were near the forest edge around Landing Lake and Twin Lakes. A few pairs were scattered through the wooded areas (not surveyed) along the Twin Lakes Road between Sections 4 and 5. Yellowlegs that forage in the Twin Lakes fen do not breed there but in nearby wooded areas.

With obvious flight displays and noisy and persistent alarm calls, yellowlegs are hard to overlook. Our count of 14 pairs in Sections 1–4 is probably 80% accurate; data for Section 5 are less good. We estimated 30–40 pairs in the area surveyed. We cannot make a confident estimate of the total population because we did not survey forest edge situations farther inland, as at Twin Lakes or along Goose Creek.

Whimbrel (*Numenius phaeopus*). Whimbrel are widespread, especially in wet sedge meadows or in hummock-bogs near the treeline; few breed on the coastal tundra or east of CNSC. Territories are easy to detect because of the birds' noisy flight displays and propensities for chasing aerial predators (ravens, gulls, jaegers) that approach their nest. We determined 95 territories and found 40 nests. Given the Whimbrel's conspicuous behavior and Lin's detailed studies in 1994–1996 (Lin 1997), we are confident of having found at least 90% of the territories and estimate the local population at about 105–110 pairs.

Hudsonian Godwit (*Limosa haemastica*). Hud-

sonian Godwits breed most commonly in sedge meadows near the treeline. The general location of territories is easy to determine by watching flight displays early in the season. By mid-season the birds become less obvious. We located 36 territories (but only five nests, which are extremely difficult to find) and estimate our success at about 70%.

Semipalmated Sandpiper (*Calidris pusilla*). In 1993–1996, the entire population west of CNSC consisted of 5–9 pairs, all in Section 3 (Jehl unpublished). When the nesting area flooded in 1997, only two pairs bred. At Gordon Point (Section 4) we found about five pairs, all restricted to the outermost beach. Between CNSC and Gordon Point the species is virtually absent (one pair).

Least Sandpiper (*Calidris minutilla*). Least Sandpipers are hard to census because they do not display as conspicuously as some other species and sit tightly on nests. Based on our experience in finding nests in intensively studied areas in good habitat, we estimate that combined study plot/transect procedures in 1997 located 40–50% of the population (36 territories, 17 nests), which would total about 80–100 pairs.

Dunlin (*Calidris alpina*). Intensive studies (JRH unpublished) through the 1990s delineated the localized breeding distribution of the Dunlin. Nests can be found fairly easily, and territories are evident from the flight displays of males, which often involve other species. From 1991–1996 Jehl estimated the local population at about 80 pairs; we estimated 76. Very few can remain undetected.

Stilt Sandpiper (*Calidris himantopus*). Stilt Sandpipers have been studied locally since the 1930s (Jehl 1970, summarized in Klima and Jehl 1998). Flight displays involving several individuals or other species may be continued rather late in the season, making it easy to locate territories. In 1997, as in other recent years, Stilt distribution was patchy. Our finding of 36 territories (12 nests) agreed with other estimates in the 1990s (Jehl unpublished), which indicated a population of 50–60 pairs. We did not find this species in Section 4 east of CNSC.

Short-billed Dowitcher (*Limnodromus griseus*). Dowitchers nest in wet sedge meadows, occasionally north to the Launch Road. Males do not sing as much or as long as other species, making territories harder to detect, and after nesting starts dowitchers become even less conspicuous; nests are found only by accident. We found 24 territories and six nests. Although occurring in all areas, dowitchers are commonest in Section 1, where we probably detected only about half of the population. Counts in Sections 2–5, however, are probably accurate to within 25%. We estimated the population at 50–60 pairs.

TABLE 2. Historical impressions of shorebird abundance at Churchill, Manitoba. For locations of main areas surveyed see Figure 1.

Species	Taverner and Sutton (1934)	Grinnell and Palmer (1941)	Allen (1945, 1946)	Breckenridge et al. (1954)	Jehl and Smith (1970)	This paper	Overall change - 1930-1990s
American Golden- Plover	Common summer resident (but only 6 nests in 2 years)	Occasionally seen; no nests found	Scarce; 6 pairs in 15 sq. mi.	Evidently very rare; no nests	"Fairly common summer resident"	Common	Great increase
Semipalmated Plover	Nests abundantly, many nest found	Abundant everywhere		Abundant	Common summer resident	Fairly common	Probable decrease
Killdeer	Uncommon and local	Several pairs by townsite	Apparent increase; 5-6 pairs	Rare	"Uncommon and summer resident"	Uncommon and local	Slight increase
Lesser Yellowlegs	Common summer resident	Common in forested areas		Abundant	"Common to abundant summer resident at the treeline"	Fairly common	Decrease
Spotted Sandpiper	Rare and local summer resident	One pair	Noticeable increase	Unrecorded	Rare and local	Rare and local	Unchanged
Whimbrel	Common summer resident	"Plentiful"	Pronounced increase since 1934; "one pair for every quarter mile of tundra"	Abundant	"Common to abundant summer resident near the treeline"	Common	Probable decrease
Hudsonian Godwit	Very rare	Seen occasionally; up to 4 at one time	Slight increase since 1934	Common	"Common summer resident at the treeline"	Fairly common	Great increase
Semipalmated Sandpiper	Abundant summer resident	"Plentiful"	Commonest sandpiper	Unrecorded	Fairly common locally	Virtually extirpated	Great decrease
Least Sandpiper	Nests abundantly	3 nests found		Fairly common	Common to abundant	Uncommon	Great decrease
Dunlin	Common summer resident	2 nests found on wet tundra	Unchanged since 1934	Unrecorded	Common but local	Fairly common but locally	Decrease
Stilt Sandpiper	One of the most common breeding shorebirds	"Abundant"	Less common than in 1934	Rare	Common	Uncommon	Great decrease
Short-billed Dowitcher	Rare and local summer resident	One nest; Rare	Slight increase since 1934	Uncommon	Fairly common	Fairly common	Increase
Common Snipe	Fairly common summer resident	Common, heard throughout the day		Abundant	Common to abundant	Fairly common	Unknown
Red-necked Phalarope	Breeds abundantly	Numerous	Abundant	Unrecorded	Locally common	Uncommon and local	Great decrease

Common Snipe (*Gallinago gallinago*). The distribution of snipe was quite local. We found them mainly in the deeper marshes near willow thickets along the treeline; a few pairs occurred north to the Hudson Bay shore (Bird Cove). Because snipe have crepuscular displays, they cannot be censused reliably by our techniques, and we found no nests. We identified 20 territories, of which 13 were in Section 1, and estimated 40 pairs in the survey area.

Red-necked Phalarope (*Phalaropus lobatus*). Phalaropes are scarce and local, usually nesting in pond habitats in association with Arctic Terns (*Sterna paradisaea*). In Sections 1–3 and 5 we found only 13 pairs. That figure may be slightly conservative, because a few pairs sometimes breed in areas of the large Akudlik Marsh (Section 1) that we could not study in detail because of its designation as a sanctuary. In Section 4, 2–3 pairs nested near Bird Cove and perhaps 6–10 pairs at Gordon Point, which we could only survey briefly. We doubt that there are more than 30–40 pairs in the survey area. Otherwise we know only of several pairs that sometimes nest on the townsite ponds and 1–2 pairs at West Twin Lake.

Discussion

Approximately 800 pairs of shorebirds (slightly greater than 0.1 pair ha⁻¹) nested in the study area in 1997. That total, and the estimate by species, is consistent with other data obtained by JRJ throughout the 1990s. Historical data are scarce and allow only qualitative comparisons, but several kinds of evidence including (1) writings of early naturalists (e.g., Taverner and Sutton 1934; Grinnell and Palmer

1941; Jehl and Smith 1970; and others below), (2) large specimen holdings in many museums (Jehl personal observations), and (3) data from plots censused in the 1960s and 1990s (Jehl unpublished) leave no doubt that shorebirds are far scarcer than they were in the 1930s and 1960s. The dearth is so obvious that visiting birders often inquire “where are the shorebirds?” — a question that would have been ludicrous only three decades ago. For instance, the Semipalmated Sandpiper, once the most abundant species (Taverner and Sutton 1934; Allen 1945), is virtually extirpated. The Least Sandpiper, locally fairly common in the 1960s, occurs in greatly reduced numbers. And observations that one or more Red-necked Phalaropes could be found on every lakelet or pool (Taverner and Sutton 1934: 49), or that Stilt Sandpipers nest “quite commonly” (Farley 1936), “with ‘scores’ displaying at the same time (Sutton 1961), are so contrary to current status that future ornithologists may find these impressions hard to reconcile. On the other hand, Hudsonian Godwits, thought to be on the verge of extinction as late as the 1940s, have increased, and the Golden-Plover has gone from being one of the least common species to perhaps the commonest.

Some of these differences can be appreciated in the writings of ornithologists who have commented on general status (Table 2), or have either ranked relative abundance or provided enough information that we have tried to do so (Table 3). No two studies are fully comparable because no two involved the same localities or habitats (Figure 1 B–E). The rankings of Breckenridge et al. (1954) are not very informative because that party was based near the treeline at

TABLE 3. Ranking of relative abundance of shorebirds at Churchill, Manitoba.

Species	Taverner and Sutton (1934) ¹	Allen (1945) ²	Breckenridge et al. (1954) ³	Jehl and Smith (1970) ⁴	This paper
American Golden-Plover		11	—	11	1
Semipalmated Plover	2	3	2	4	5
Killdeer		12	11	13	12
Lesser Yellowlegs		6	3	2	9 ⁵
Whimbrel		4	1	3	2
Hudsonian Godwit		13	6	10	8
Semipalmated Sandpiper	1	1	—	9	13
Least Sandpiper	3	2	7	1	3
Dunlin		9	—	8	3
Stilt Sandpiper	4	8	10	5	6
Short-billed Dowitcher		10	8	6	6
Common Snipe		7	4	7	10
Red-necked Phalarope		5	5	11	11

¹Based on our interpretation of Taverner and Sutton 1934.

²Allen ranked Spotted Sandpipers (not treated herein) as 13, Hudsonian Godwit 14.

³Breckenridge et al. inexplicably ranked Sanderling as 9. That species does not breed within hundreds of miles of Churchill.

⁴Based on Jehl and Smith 1970, and unpublished field notes.

⁵Relative abundance underestimated because survey areas did not include major habitat.

Landing Lake, where many species are absent. Jehl's observations from the 1960s (summarized in Jehl and Smith 1970) provide the best basis for comparison, as they encompassed nearly all the areas searched by earlier workers, as well as most of the 1997 survey area; the exceptional areas were Section 5 and the tundra east of CNSC (Section 4), to which access was then severely limited owing to military operations.

In general, it appears that the relative abundance of most species was fairly stable from the 1930s through the 1960s, but that important changes took place over the following three decades. The causes are probably complex and vary by species. Many breeding areas that were productive in the 1960s now hold few shorebirds, having been heavily modified by overgrazing geese (Abraham and Jeffries 1997; Jehl unpublished). In other cases habitat changes are surely involved, particularly near areas of human habitation. Yet the declines in some species are not simply local phenomena. Semipalmated Sandpipers and Red-necked Phalaropes have declined at La Pérouse Bay, 20–25 km east of CNSC (Gratto-Trevor 1993/94). Other population effects likely involve conditions on wintering grounds or migration routes. Censuses made every decade or so may resolve the relative importance of local vs. regional factors affecting shorebird numbers. Such data are important because of indications that shorebirds are undergoing severe declines (Morrison et al. 1994; Morrison 2001). They will also help maintain and extend what may be the best long-term record of birdlife anywhere in the subarctic (Houston et al. 2002; Jehl unpublished).

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species in Sections 4 and 5. E. Nol, C. Gratto-Trevor, G. Morrison, and A. J. Erskine provided helpful comments on a draft manuscript.

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Grizzly Bear, *Ursus arctos*, Usurps Bison Calf, *Bison bison*, Captured by Wolves, *Canis lupus*, in Yellowstone National Park, Wyoming

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We describe an adult Grizzly Bear (*Ursus arctos*) usurping a Bison (*Bison bison*) calf from a pack of five Wolves (*Canis lupus*) attempting to kill the Bison in Yellowstone National Park during early spring. Five Wolves grabbed the hind end and neck of the calf while it was trailing behind two adult male Bison. In 3 minutes a Grizzly Bear arrived and displaced the two Wolves attacking the hind end. For 1 minute the Grizzly Bear attacked the rear of the Bison while three Wolves attacked the front end. The Grizzly Bear subsequently pulled the struggling calf from the Wolves and made the kill. The Wolves were unable to displace the Grizzly Bear from the carcass. Our observation demonstrates the capacity for Grizzly Bears to exploit the predatory abilities of Gray Wolves restored to Yellowstone National Park. Kleptoparasitism by Grizzly Bears on Wolf-captured ungulates may be a selective pressure promoting group living in Wolves, and could provide an important new food resource to threatened Grizzly Bears in the Greater Yellowstone Ecosystem.

Key Words: Grizzly Bear, *Ursus arctos*, Wolf, *Canis lupus*, Bison, *Bison bison*, predation, kleptoparasitism.

Wolves (*Canis lupus*) and Grizzly Bears (*Ursus arctos*) commonly interact in the defense of offspring or in competition for carcasses (Murie 1944; Ballard 1982; Hornbeck and Horejsi 1986; Hayes and Mossop 1987; Hayes and Baer 1992; Servheen and Knight 1993; Kehoe 1995; Mech et al. 1998). Lent (1964) reported tolerance between a Grizzly Bear and a Wolf feeding simultaneously on a Caribou (*Rangifer tarandus*) carcass. During competition for carcasses, Murie (1944:204) observed that in general, “the Wolves are the losers and the meat-hungry bears are the gainers”. The ability of Grizzly Bears to contest carcasses successfully could be a factor favoring the evolution of group living in Wolves, and may be an important consideration in the conservation of Grizzly Bears in the Greater Yellowstone Ecosystem (GYE). Here we describe the first observation of a Grizzly Bear usurping a Bison captured by Wolves.

The Wolf-Grizzly Bear interaction was observed near Pelican Valley, Yellowstone National Park, Wyoming (44° 38' N, 110° 13' W) on 24 March 2000. The interaction occurred in an open creek drainage bordered by forests composed primarily of Lodgepole Pine (*Pinus contorta*). The area lies at 2432 m and is subjected to long, cold winters, with snow thickness from 33–160 cm. To survive in Pelican Valley during winter, Bison rely upon an archipelago of snow-free and nearly snow-free areas created by geothermal activity (Meagher 1976). Thermal features (hotsprings, fumaroles, etc.) and patches of thermally influenced warm ground are scattered throughout the area. South-facing and wind-blown slopes provide additional habitat for

bison. Winter forage includes various species of sedge (*Carex* spp.) and grass (Meagher 1973).

From a prominent hilltop, we observed the Wolf-Grizzly interaction using a 56× Nikon spotting scope from a distance of 6.0 km. Observations were timed with a digital stopwatch and recorded on a portable voice recorder. The pack of five adult Wolves first encountered the herd of 59 Bison on 23 March at 09:08, and a Grizzly Bear first appeared at 12:31 while running toward the Wolves as they made a failed attempt to kill a Bison. In each of two subsequent attacks observed that day, the Grizzly Bear ran immediately behind or alongside the pursuing Wolves. Two additional adult-size Grizzly Bears appeared traveling together toward the Wolves at 18:38. Subsequent play behavior suggested that the bears were a two-year-old sibling pair.

The next day, 24 March, 12:13–18:19, 1–5 ($\bar{x} = 3$) Wolves made a series of 14 attacks, alternately attacking and resting, on a Bison group containing nine adult/juvenile bulls and one 11-month-old calf of unknown sex. The group of 10 Bison had remained in the area while the remainder of the herd fled when the pack pursued a single unidentified Wolf approaching the Bison at 11:19. The unidentified Wolf was not wearing a radio-collar and was presumed to be either an unrelated trespasser or an unwelcome relative. The pack mobbed the unidentified Wolf, but allowed it to escape.

Wolf attacks on Bison lasted 2–11 minutes ($\bar{x} = 6$ minutes), and involved Wolves lunging at Bison while they stood grouped on a thermal feature ($n = 12$) or running single file through deep snow

between thermal features ($n = 2$). Wolves targeted the calf during all attacks. In four attacks 1–2 wolves grabbed the calf and inflicted visible damage to the rump and flanks but failed to make the kill. In all but the final attack 1–5 bulls ($\bar{x} = 2$) defended the calf by charging and kicking at the Wolves. A bull successfully kicked a Wolf in only two attacks.

During Wolf attacks Grizzly Bears watched at a distance greater than 15 m ($n = 2$), approached and watched from less than 15 m ($n = 2$), approached and walked the perimeter of the attack area ($n = 3$), and approached and grabbed prey ($n = 1$). When walking the perimeter of the attack area Grizzly Bears often displaced resting Wolves not participating in the attack. Grizzly Bears were not visible in the remaining six attacks due to vegetation and topography; however, their ongoing presence was inferred when visible between attacks. For example, at 15:07, during a pause between the fifth and sixth attacks, one grizzly reappeared from behind a screen of trees and rushed the wounded calf, which stood in the center of nine resting bulls. The grizzly halted and walked back behind the trees when the nine bulls stood up and gathered around the calf.

The final attack was preceded by a 3.5 hour standoff between Wolves and Bison on a thermal feature at the foot of a small snow covered ridge. During this period Wolves made periodic attempts to grab the calf but were repelled each time by the bulls. The standoff ended when seven bulls walked away from the thermal feature and ascended the ridge, leaving two bulls to defend the calf. After a failed attempt to capture the calf, the Wolves left the thermal feature at 18:05 and trotted toward the seven bulls. Meanwhile, one Grizzly Bear appeared and began walking toward the two bulls and calf.

For clarity the events involving the final attack are listed below chronologically.

- 18:14 The two bulls, followed closely by the calf, walked away from the thermal feature and began ascending the ridge single file toward the seven bulls and five resting Wolves. The grizzly continued to approach the three Bison.
- 18:15 Sighting the oncoming Bison the pack arose and approached the two bulls and calf from the west while the grizzly approached from the east. The calf moved with difficulty through the snow and trailed 10–15 m behind the two bulls.
- 18:19 All five Wolves walked past the two bulls and four Wolves grabbed the calf; three grabbed the hind end and one grabbed the flank. Seconds later a fifth Wolf grabbed the neck. The two bulls continued walking and joined the seven other bulls.
- 18:20 The grizzly continued to approach from the east, nearing the calf and Wolves.
- 18:21 Three Wolves released the calf and charged the grizzly while the remaining two Wolves continued to grab the hind end of the calf. As the Wolves started to lunge at the grizzly it rose to its hind legs, quickly fell back to all four feet, and fled with the three Wolves in pursuit. Within seconds, the grizzly turned, ran past the pursuing Wolves, and back to the calf.
- 18:22 The grizzly forced the two Wolves from the calf's hind end and began to attack the calf with its forepaws. The two Wolves, joined by a third, then grabbed the front end of the calf.
- 18:23 Three Wolves bit the front end of the calf while the grizzly swatted at the hind end.
- 18:24 The grizzly pulled the calf from the Wolves, dragged it to the ground, and began to feed. The Wolves did not contest the carcass any longer. Four Wolves disappeared over the ridge while one Wolf stood by and watched the grizzly feed.
- 18:26 Two Wolves returned from behind the ridge and rested along side the other Wolf approximately 5 m from the carcass and the feeding bear. Meanwhile, the nine bulls began to walk single file back along the ridge toward the thermal area, the feeding grizzly, and the resting Wolves.
- 18:41 As the bulls approached to within 5 m, the grizzly abandoned the carcass and disappeared over the ridge. Nearly simultaneously, two Wolves reappeared, and all five Wolves repossessed the carcass and started feeding. The first bull to run past the carcass briefly displaced the Wolves. Once the bull was past the Wolves returned and continued to feed. Five more bulls ran past the feeding Wolves singly or in pairs. Two Wolves briefly chased a pair of Bison as they ran past and then returned to the carcass.
- 18:53 The pair of sibling grizzlies appeared at the thermal area and began to approach the carcass and the feeding Wolves.
- 18:54 The two grizzlies veered and began walking away from the carcass.
- 18:58 The last bull, which was also the smallest, ran past the feeding Wolves. Again, two Wolves briefly pursued the bull and returned to the carcass.
- 19:00 The single grizzly returned to the carcass from behind the ridge, displaced all five Wolves, and resumed feeding. Two Wolves disappeared over the ridge immediately, while three Wolves remained standing around the carcass, watching the grizzly feed.

19:06 The single grizzly continued to feed on the carcass without interruption until observation ended due to darkness.

Initial observation at 07:00 the following day 25 March, found one grizzly feeding on the carcass, while three Wolves were sleeping 25 m away. The grizzly fed until 11:51, and then walked over the ridge and out of view. During this period the Wolves approached the grizzly to within 5 m but did not actively contest the carcass. Once the grizzly left the carcass three Wolves returned and fed until at least 12:29, at which time the carcass was pulled over the ridge and out of view.

The Wolves' failure to seriously challenge the grizzly once the Bison was usurped may have been influenced by the tearing of the carcass into two or more parts during the struggle for possession. This explanation is supported by our inspection of the kill site, which revealed the remains of a front and rear leg over the ridge where the Wolves and the grizzly disappeared. It is possible that the grizzly fed on these parts when it was displaced from the carcass by the nine passing bulls. Likewise, when the grizzly was feeding on the carcass and only one to three Wolves were visible, the remaining Wolves were probably feeding on these same parts. Based on examination of two mandibles found at the kill site the age of the Bison was confirmed to be 11 months.

The sequence of events that led to the Grizzly Bear usurping the Bison calf from the Wolves began with the unusual association between the calf and the bulls. While bulls are known to defend calves from Wolves (Carbyn and Trottier 1988; Carbyn et al. 1993), the occurrence of a calf within a Bison group composed exclusively of bulls has not been previously reported for a wild Bison population. Bison calves are usually found in large mixed herds containing females of all ages, yearlings, and most males two to three years old (Meagher 1986). Explanations include (1) random association, (2) calf was orphaned, and (3) if a male, the calf deliberately joined the bull group. The cow-calf bond breaks earlier for males than for females (Lott and Minta 1983; Green et al. 1989), and calves not associating with a cow are subject to more aggression than calves with cows (Coppedge et al. 1997). Frequent feeding displacement during early spring food scarcity (Rutberg 1986) may have led the 11-month-old calf to join the smaller bull group.

Kleptoparasitism by Grizzly Bears and other scavengers on Wolf-captured ungulates could be a factor favoring the evolution of group living in Gray Wolves. In African Wild Dogs (*Lycaon pictus*) kleptoparasitism by Lions (*Panthera leo*) and Spotted Hyenas (*Crocuta crocuta*) is considered an important factor in the evolution of group living (Fanshawe and FitzGibbon 1993; Creel and Creel 1996; Carbone et al. 1997). Wolves might respond to klep-

toparasitism from Grizzly Bears by increasing group size and thereby increase access time at carcasses. Future studies should attempt to assess whether larger packs of Wolves are more successful at defending carcasses from Grizzly Bears and whether increases in access time fully compensate for reductions in per capita intake due to larger pack size (Schmidt and Mech 1997). Interestingly, the Wolves reported in this observation rejected an opportunity to increase the size of their group when they ran off an unidentified Wolf, suggesting that factors unrelated to prey capture or carcass defense may be more important to group formation.

While an earlier assessment predicted that Wolves restored to Yellowstone National Park would not affect the Yellowstone Grizzly Bear population (Servheen and Knight 1993), the capacity for Grizzly Bears to usurp Wolf-killed ungulates suggests the potential for a positive effect. Wolf-killed ungulates may be an important new high-quality food resource for Grizzly Bears in the GYE, where the future of many traditional Grizzly Bear foods is uncertain (Mattson and Reid 1991). An increase in the availability of meat to Grizzly Bears could positively influence several population parameters including adult female body mass, litter size, and population density (Hilderbrand et al. 1999).

Whether Yellowstone Grizzly Bears realize a population level benefit from Wolf-killed ungulates may largely depend on seasonal and demographic variation in access to Wolf-killed ungulates. Grizzly Bear population densities have been found to correlate positively with fall meat availability, in part because meat consumed in fall is more important for successful cub production and hibernation than meat consumed in spring (Hilderbrand et al. 1999). Fall is also a period when Wolf persistence at kills may be greater due to lower kill rates compared to spring (Smith unpublished), thus potentially limiting grizzly access to Wolf-killed ungulates. The ability of Grizzly Bears to usurp and maintain possession of a Wolf-killed ungulate may also be affected by Grizzly Bear age, sex, and reproductive status. Specifically, females with offspring or smaller bears of either sex may be less capable than adult males in usurping a carcass from Wolves, and subsequently keeping the carcass from other grizzlies. Adult male grizzlies are more aggressive than other age and sex classes and tend to dominate localized high-quality food resources (Craighead et al. 1995). As a result, adult male grizzly dominance at Wolf-killed ungulates may restrict access to Wolf-killed ungulates among other members of the GYE grizzly population (i.e., reproductive females).

If Wolf-killed ungulates are unavailable to grizzlies in the fall and/or consumed mainly by adult male grizzlies, a population level benefit to GYE

Grizzly Bears due to Wolf-killed ungulates seems unlikely. However, further research is necessary to understand the seasonal and demographic variation in Grizzly Bear access to Wolf-killed ungulates.

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Notes

An Observation of a Mallard, *Anas platyrhynchos*, Feeding on a Wood Frog, *Rana sylvatica*

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Eaton, Brian R., and Zachary C. Eaton. 2001. An observation of a Mallard, *Anas platyrhynchos*, feeding on a Wood Frog, *Rana sylvatica*. *Canadian Field-Naturalist* 115(3): 499–500.

Mallards (*Anas platyrhynchos*) will feed opportunistically on vertebrates, and have been reported feeding on amphibians in Europe; similar reports in North America are rare. Here we report on an observation of a Mallard feeding on an adult Wood Frog (*Rana sylvatica*) in April 1999, in Edmonton, Alberta.

Key Words: Mallard, *Anas platyrhynchos*, Wood Frog, *Rana sylvatica*.

On 24 April 1999, we were searching for Wood Frogs (*Rana sylvatica*) and Boreal Chorus Frogs (*Pseudacris triseriata maculata*), and their eggs, in a series of pools in Whitemud Park in Edmonton, Alberta (53° 33' N, 113° 28' W). These stagnant pools seemed to be the remnants of a braided stream, with a width of approximately 1 metre. Both Wood and Chorus Frogs were calling in the area, and male Wood Frogs were visible on the surface of the water; we found no egg masses.

While searching, we disturbed a female Mallard Duck (*Anas platyrhynchos*) from under vegetation overhanging a pool; she swam slowly away from us. Several minutes later, the same Mallard was seen biting at what proved to be a Wood Frog. She flipped the frog out of the water and on to the bank, and, after some struggle grasped the frog in her bill, tipped her head up and back, and swallowed the frog head first. We were able to train binoculars on the duck as she swallowed, and based on the size and shape of the hind legs were able to identify the prey as an adult Wood Frog. The entire sequence of events, from attack to complete consumption of the frog, lasted approximately 30 seconds.

After eating the Wood Frog, the Mallard settled on the bank where she had captured the frog. She remained there several minutes and reacted once more to movement in the water, probably the activity of another frog. When reacting she jerked her head up and forward from its resting position and stood. She did not, however, pursue more frogs.

Predation on amphibians by members of the Anseriformes is not often reported in the literature. In a review of amphibians and reptiles as prey of

birds in southwestern Europe, Martín and López (1990) only listed one general reference, and one specific reference, for predation on amphibians by ducks, geese, and related taxa. In North America, McAtee (1918) found remains of frogs in one of 622 Black Duck (*Anas rubripes*) stomachs. Mabbott (1920) found frog remains in one of 790 Pintail (*Anas acuta*), and two of 413 Wood Duck (*Aix sponsa*) stomachs. Mallory and Larivière (1998) collected a Wood Duck on 15 September 1997 with three Mink Frogs (*Rana septentrionalis*) in her esophagus; SVL of all three frogs was approximately 45 mm. Trochell and Watermolen (1995) observed two adult Canada Geese (*Branta canadensis*) feeding on newly metamorphosed American Toads (*Bufo americanus*) emerging from a small pond in Wisconsin in June 1994. These few reports suggest that, although amphibians may be taken by anseriforms, they do not usually form a large part of the diet.

To our knowledge, there are no published reports of Mallards eating Wood Frogs, although the use of these frogs as prey by Mallards is not surprising. McTee (1918) found frog remains in 19 of 1725 Mallard stomachs. Bent (1923) stated that Mallards take the “occasional slug, snail, frog, or lizard”, and Bannerman (1958) mentioned that “Frogs, tadpoles, and spawn are greedily devoured” by Mallards; neither author supplied specific information. Cramp (1977) also listed amphibians among prey taken by Mallards. Sugden and Driver (1980) observed a Mallard with a brood of full-grown young capture and swallow a salamander (*Ambystoma* sp.) on 2 August 1978; the authors did not specify whether the encounter occurred on land or in the water, or the

size of the salamander. Based on distribution maps, the salamander must have been a subspecies of Tiger Salamander (*Ambystoma tigrinum*); adults of that species range in size from 75 to 162 mm SVL (Stebbins 1985).

More recently, Mjelstad and Sætersdal (1989) observed Mallards eating the Common Frog (*Rana temporaria*) in western Norway. Mjelstad and Sætersdal (1989) were not able to measure the frogs being taken by Mallards, but Common Frogs in Switzerland range in size from 59 to 94 mm in snout-to-vent length (SVL) (Ryser 1996). We were unable to measure the Wood Frog we observed being consumed by the Mallard, but adult Wood Frogs in Alberta range in size from 30 to 60 mm SVL (Russell and Bauer 2000). Captive Mallards will eat Boreal Toad (*Bufo boreas*) tadpoles (Jones et al. 1999), even though toad tadpoles are generally considered noxious to most potential predators. These observations suggest that Mallards may prey upon a variety of amphibians, some of which are quite large.

Amphibians may represent an important protein source for both male and female Mallards during mating and egg-laying (Mjelstad and Sætersdal 1989). Eldridge and Krapu (1988) showed experimentally that female Mallards on a high protein diet produced larger clutches and eggs than Mallards on a protein-poor diet. Some species of amphibians contain a higher concentration of protein in their bodies than either birds or small mammals, and represent higher-quality prey than these other two groups (Burton and Likens 1975). In some areas, this high-quality food becomes available to Mallards during the egg-formation period, as was the case in Norway. As a result, frogs were taken regularly by both male and female Mallards during diving, gleaning, and kleptoparasitic activities (Mjelstad and Sætersdal 1989).

Observations of waterfowl preying on amphibians are relatively rare, but indicate that a wide range of amphibians, both in terms of size and species, will be taken when available. Even if the observed level of predation by waterfowl on amphibians is an accurate reflection of the actual rate at which they are consumed by ducks and geese in the wild, amphibians are high quality prey that may be important protein and energy sources for individual waterfowl.

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First Record of an Anomalously White Killer Whale, *Orcinus orca*, Near St. Lawrence Island, Northern Bering Sea, Alaska

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Speckman, Suzann G., and Gay Sheffield. 2001. First record of an anomalously white Killer Whale, *Orcinus orca*, near St. Lawrence Island, Northern Bering Sea, Alaska. *Canadian Field-Naturalist* 115(3): 501–502.

An anomalously white Killer Whale (*Orcinus orca*) was sighted swimming with a group of normally-pigmented Killer Whales near St. Lawrence Island in the northern Bering Sea. The white whale had a tall, straight dorsal fin, indicating a mature male. Most sightings of white or albinistic Killer Whales have been of individuals that were smaller than their companions. This sighting of an adult white male is unusual, given that albinistic individuals may not survive as long or attain as large a size as their normally-pigmented conspecifics due to the wide range of physical and physiological abnormalities commonly associated with partial or complete albinism.

Key Words: Killer Whale, white cetacean, *Orcinus orca*, albinism, Bering Sea.

On 27 August 1993, we sighted an all-white Killer Whale (*Orcinus orca*) swimming with approximately 11 other Killer Whales 5.5 km southwest of St. Lawrence Island, in the northern Bering Sea, Alaska at 63°47'N, 171°45'W. The water depth was <50 m and sea state was calm. The whales were first spotted about 500 m from our vessel, swimming slightly towards us and parallel to our course, and we could see them clearly through 10×40 binoculars. The white whale was large with a tall, straight dorsal fin, indicating a mature male. It was a creamy yellowish color over all of its exposed body—the head, back, and dorsal fin. There did not appear to be any dark pigmentation. The placing of the typical pigmentation pattern of a Killer Whale was visible, with the normally white saddle behind the dorsal fin showing as a lighter, whiter color. We were unable to see the whale's eyes so cannot confirm it was a true albino (pigmentless pink eyes) or leucistic (normal dark eyes). This represents the first report of a white or possibly albinistic Killer Whale for the Bering Sea.

The group we encountered included a second mature male with a tall dorsal fin. This second male was normally-pigmented and its fin was slightly taller than that of the white whale. The remaining whales were normally-pigmented adult females or subadults. The closest approach of the group was about 400 m, and all of the whales, including the white one, were behaving normally, swimming and surfacing for air.

Anomalously white cetaceans are reported infrequently. Hain and Leatherwood (1982) and Fertl et al. (1999) reviewed the literature and compiled unpublished observations, and found that such individuals have been sighted in 20 cetacean species. Although details are scarce, most sightings of white Killer Whales have been of individuals that were

reported as “small” or smaller than their companions (Carl 1959; Pilleri and Pilleri 1987; Scheffer and Slipp 1948). There are two reports of white female Killer Whales that appeared to have calves, both of which were also white (although one calf had a black border on the dorsal fin: Carl 1959). These breeding females must have been at least 15 years old (Olesiuk et al. 1990). The tall dorsal fin of the white male we sighted indicates that he was physically mature and therefore at least 21 years of age (Olesiuk et al. 1990).

Our sighting of such a long-lived albinistic Killer Whale is unique, because on average, albinistic individuals may not survive as long or attain as large a size as their normally-pigmented conspecifics. Hain and Leatherwood (1982, from Searle 1968) noted a wide range of pathological conditions that are commonly associated with partial or complete albinism. These included lowered fertility, anemia, defects of the eyes and ears, defects of the central nervous system, and increased susceptibility to infection. Other conditions also occur that can mimic albinism. A captive “white” Killer Whale with pale, ghostly outlines of the usually white markings was diagnosed with Chediak-Higashi syndrome (Ridgway 1979), which presumably caused or contributed to its death. Most of the conditions that accompany lack of pigment would increase mortality rates, diminishing the average body size and shortening the average lifespan.

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Evidence for Double Brooding by a Mallard, *Anas platyrhynchos*, in Eastern South Dakota

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Documentation of double brooding by ducks is uncommon in the northern hemisphere. We report double brooding by a Mallard (*Anas platyrhynchos*) in eastern South Dakota during 1999. A radio-marked female hatched her clutch, reared her brood to 15–25 d post-hatch, and re-nested. The female successfully hatched and reared her second brood to 50 days post-hatch. These data plus a band recovery in October of 2001 from the first brood provide circumstantial evidence of double brooding by this female.

Key Words: Mallard, *Anas platyrhynchos*, brood rearing, double brooding, second nesting.

Renesting by ducks after disturbance during laying, incubation, or after clutch loss is not uncommon (Sowls 1955; Swanson et al. 1986). Some duck species in North America will re-nest after brood loss, especially if brood mortality occurs soon after hatch (Bjarvall 1969; Doty 1975). Few cases in North America, with the exception of Wood Ducks (*Aix sponsa*) (Fredrickson and Hansen 1983; Moorman and Baldassarre 1988; Fielder 1992), document the production of a second brood when at least one duckling from the first brood is known to have survived (double brooding). In the southern hemisphere, evidence for double brooding exists for several Australian duck species including the Pink-

eared Duck (*Malacorhynchus membranaceus*), Chestnut Teal (*Anas castanea*), Grey Teal (*Anas gibberifrons*) and Australian Wood Duck (*Chenonetta jubata*) (Braithwaite 1976a, 1976b). A White-cheeked Pintail (*Anas bahamensis*) in the Bahamas re-nested and hatched a second clutch after successfully fledging her first brood (Sorenson et al. 1992).

Eleven female Mallards (*Anas platyrhynchos*) in an unusually dense population near the Delta Waterfowl Research Station in Manitoba abandoned broods to re-nest, but fates of individual broods were not presented; this population consisted largely of artificially maintained and hatchery-reared Mallards, many of which overwintered on site (Titman and

Lowther 1975). Based on age class data and repeated observations, Bjarvall (1969) documented double brooding by two Mallards in Sweden, where ducklings from early and late broods of both females were known to have fledged. The rearing of two broods to fledge by a Mallard in North America during a single breeding season, in a natural setting, has not, to our knowledge, been documented. Here we report evidence of double brooding by a Mallard in eastern South Dakota.

In 1999, we conducted research on Mallard duckling survival at the Redetzke Game Production Area (Redetzke) in southeastern Day County, South Dakota (45°15'45"N, Longitude 97°25'00"W). Redetzke is a 160-ha semi-permanent wetland with many overwater nesting structures (Stewart and Kantrud 1971). About 70–80% of this wetland consisted of dense interspersed emergent vegetation, primarily cattails (*Typha* spp.), whereas the center remained free of emergent vegetation.

Female Mallards were captured from overwater nesting structures during incubation and fitted with 4.5-g radio transmitter using a modified Mauser attachment (Pietz et al. 1995). Ducklings from some of our marked females were also fitted with 1.5 g transmitters of the same type while still at the nest. After nest exodus, females with broods were monitored until ducklings fledged (approximately 55 days post-hatch, Bellrose 1976), contact was lost, or the adult died. Marked ducklings were also monitored until death or loss of the transmitter. Counts of ducklings within broods were scheduled every seven days but were recorded opportunistically. Female behavior was monitored daily and used to determine the presence or absence of a brood when ducklings were not seen (Bergmann 1992; Rotella and Ratti 1992).

On 13 May, a radio-marked female hatched all of 13 eggs and left her nest on 14 May; two of these ducklings were radio-marked and the remaining 11 were fitted with plasticine-filled leg bands (Blums et al. 1994). On 15 May we determined that the two radio-marked ducklings were not with the female. Upon investigation, on 18 May, we found both radio-marked ducklings and one banded duckling dead on a Muskrat (*Ondatra zibethicus*) lodge near the nesting structure. The presence of an egg tooth and progress of decomposition of the ducklings indicated that they died shortly after leaving the nest. Consistent use of dense emergent vegetation by the female compromised our ability to observe the brood regularly. Based on her movements and behavior we assumed the female was with her brood from the time of hatch until 15 days post-hatch when we first observed her accompanying a brood of eight. During the period from 29 May until 7 June we did not observe the female again, but she remained highly localized in the same marsh where she had last been observed with a brood; other radio-marked females

that lost their broods greatly increased their home range and moved erratically between wetlands. Such erratic movements among wetlands were clearly different than for females with broods (Rotella and Ratti 1992).

On 7 June, 25 days post-hatch, this female shifted her activities from the brood rearing area to the vicinity of the nesting structure where she had hatched her first brood. The female laid a second clutch of nine eggs in the original nesting structure and initiated incubation. On 12 July, 60 days after hatching the first brood, 8 of 9 eggs hatched from the second clutch. We observed ducklings with the female several times during the second rearing period; most notably, six ducklings were present on 16 August, 36 days post-hatch. Additionally, female behavior and partial brood observations suggested the presence of the second brood until 50 days post-hatch.

Survival of at least one duckling from the first brood was confirmed in October of 2001 when we received a band recovery report for a female mallard shot near Rugby, North Dakota. We believe that survival to flight of ducklings, from the 8 alive at 15 days post-hatch was probable. Mallard duckling mortality in the company of the female is low after 10–18 days post-hatch (Ball et al. 1975; Talent et al. 1983; Orthmeyer and Ball 1990; Mauser et al. 1994). Additionally, there were no catastrophic events (e.g., hail storms) generally associated with sudden and severe duckling losses. Non-catastrophic weather events (e.g., prolonged periods of rain or cold) may also adversely affect duckling survival (Korschgen et al. 1996; Krapu et al. 2000). We do not discount the possibility that periodic rainfall and temperature fluctuations may have contributed to duckling mortality in our study.

During our two-year study, radio-marked ducklings from a different brood fledged after the brood female was killed at approximately 10 days post-hatch. In a California study (Mauser et al. 1994), three radio-marked Mallard ducklings from two females that appeared to lose their entire brood joined and were fledged by other brood females. Frequent amalgamations of Mallard broods may occur in crowded populations (Titman and Lowther 1975). Fifty-two successful nests were produced from overwater nesting structures at Redetzke in 1999. Other Mallard broods used this wetland during brood rearing and the ducklings in the first brood may have joined another brood.

The female's daily behavior suggested nearly continuous brood care from hatching until the re-nesting attempt. Because there was no noticeable time-lag between leaving the first brood and initiating the second nest, copulation must have taken place while the female was rearing the first brood. We cannot account for the timing of this event. Throughout our study we observed several females with broods con-

currently accompanied by drakes and occasionally forced away from their broods. Although the exact behavioral circumstances are unknown, the evidence documents an unusual case of double brooding by this Mallard.

Oring and Sayler (1992) identify double brooding as one strategy in female ducks to adjust (increase) reproductive output. For example, double brooding by Wood Ducks in Missouri increases production by an estimated 2% annually (Fredrickson and Hansen 1983). Reports of double brooding by temperate nesting waterfowl, though, are uncommon and poorly documented. Therefore, we do not suspect that double brooding is common in Mallards, and the low frequency of occurrence precludes a significant influence on annual Mallard production.

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Opportunistic Foraging at American Elk, *Cervus elaphus*, Droppings by Clark's Nutcracker, *Nucifraga columbiana*

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In the Uinta Mountains, Utah, a Clark's Nutcracker (*Nucifraga columbiana*) was observed in August 1998 picking through a large pile of fresh soft droppings of American Elk (*Cervus elaphus*). During a five-minute period the nutcracker swallowed items recovered from the droppings 33 times, but items were too small to identify from 3–6 m distant using binoculars. Dissected droppings revealed only a few small grass and sedge seeds among undigested plant fragments. No insects were observed on or under the droppings, and the nutcracker never consumed a large quantity of the droppings, as it might have if it were seeking rare minerals or vitamins. The nutcracker pried apart some individual droppings, indicating it was searching for items contained within them, and may have been after the small, undigested seeds.

Key Words: Clark's Nutcracker, *Nucifraga columbiana*, foraging behavior, American Elk, *Cervus elaphus*, Utah.

Ingestion of fecal material is a common attribute of nest sanitation activity of passerine birds raising nestlings (Skutch 1976), including Clark's Nutcracker, *Nucifraga columbiana* (Mewaldt 1956). Fecal sacs of nestling birds may be ingested for their water, energy, and nutrients by the parents (Morton 1979). Birds also sometimes feed on the feces of another species to extract undigested food (e.g., Takenaka 1992), but feeding on another species' feces by Clark's Nutcracker is apparently unreported (Bent 1946; Tomback 1998). The European Nutcracker (*N. caryocatactes*) is reported to feed on dung (Cramp 1994), but it is not clear if the birds ingested dung or food items in or on the dung.

On 18 August 1998 we observed a Clark's Nutcracker as it foraged at fresh droppings of American Elk (*Cervus elaphus*). Our observation was made in Summit County, Utah near treeline (40°47'N, 110°36'W) at 3292 m elevation in the Uinta Mountains. Forest canopy at the site was Subalpine Fir (*Abies lasiocarpa*), Lodgepole Pine (*Pinus contorta*), and Engelmann Spruce (*Picea engelmannii*). Between 1015–1020 MDT we observed the nutcracker at close range (3–6 m) with binoculars as it probed through the droppings and swallowed 33 times unidentified items that were too small to see. The bird jabbed at the pile of droppings with a closed bill, flipped the loosened droppings aside, and sometimes pried individual droppings apart by piercing them and then slightly opening its bill, as it would open a conifer cone to extract a seed. The nutcracker's bill was covered with fecal material, and when finally flushed from the droppings it went to a nearby rock and wiped off its bill.

The elk droppings were fresh, and the soft type (Murie 1954) typically produced from a diet of green succulent vegetation. We collected a random grab-sample of 20 elk droppings (mean length \times width = 25 \times 15 mm), 10 of which (total dry weight = 8.3 g)

we later dissected and examined with a microscope. The pellets were composed largely of coarse and fine undigested plant fragments. No insect eggs, larvae or large seeds were present, but we recovered eight small seeds (mean length \times width = 1.5 \times 1.0 mm) of sedge (*Carex*) and grass (*Poa*). We probably missed a few small seeds during our dissections, but the droppings were composed mostly of non-seed material.

Nutcrackers feed on a diverse variety of items, including seeds, carrion, insects, and small vertebrates (Bent 1946; Goodwin 1976; Mulder et al. 1978; Cramp 1994; Tomback 1998), and are considered opportunistic foragers. There are at least three explanations for the apparent behavior of the nutcracker we observed, two of which we exclude.

First, the bird could have been searching for insects associated with the droppings. Nutcrackers have been reported hunting insects hidden under dry cow dung by flipping over individual droppings (Goodwin 1976). No insects were observed on, under, or in the elk droppings, nor did we observe the nutcracker actively hunting and consuming insects even though we were close enough to detect this activity. This eliminates the possibility that the bird was hunting for insects on or under the droppings. Second, the nutcracker could have been seeking nutrients or vitamins in the elk droppings. Because we never saw the bird consume a whole dropping or large dropping fragment, even though the bird could easily have done so, this is an unlikely explanation for why the nutcracker was feeding at the elk droppings, and remained at them for five minutes. Furthermore, the nutcracker's behavior of splitting open some of the individual droppings indicated it was searching for items contained in the droppings and was not after the droppings themselves. Third, the nutcracker could have been searching for undigested plant material and seeds in the elk

droppings. We favor this third explanation as the most plausible explanation for the unusual foraging behavior we observed, or at least what initially attracted the nutcracker to the droppings.

The few seeds we found in the droppings were quite small, however, seemingly a very small food reward for the nutcracker. Nevertheless, small seeds have been reported previously in stomachs of Clark's Nutcracker (Giuntoli and Mewaldt 1978). It has been suggested that some of these seeds may have been ingested with fruits (Giuntoli and Mewaldt 1978), but our observation indicates that nutcrackers might also actively seek small seeds from novel sources. Perhaps foraging at animal dung is more likely to occur when the fall harvest of ripening conifer seeds (Tombback 1978) coincides with years of low cone production, inducing nutcrackers to seek food from other sources to supplement their diet of conifer seeds. Nevertheless, absence of additional observations of foraging behavior at ungulate dung indicates it is probably a rare activity at any time.

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Gillnet Survival and Healing by a Porbeagle, *Lamna nasus*

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A 182 cm fork-length female Porbeagle, *Lamna nasus*, was captured on the Scotian Shelf south of Halifax (42°53'N, 62°53'W) with a square of monofilament gillnet mesh almost totally embedded in its snout. Besides this shark's strange "whiskered" appearance, gross inspection revealed it to be healthy. To our knowledge this report is the first documenting the healing of a shark after a net contact injury.

Key Words: Porbeagle, *Lamna nasus*, Scotian Shelf, net contact injury, healing.

Porbeagles, *Lamna nasus*, are sharks with large eyes, short snouts, long gill slits, and chubby appearances that are relatively common in cooler waters throughout the North Atlantic. While they are often found about the offshore fishing banks, they are also occasionally seen inshore (Bigelow and Schroeder 1953; Compagno 1984). Like all lamnids, the

Porbeagle is a swift and voracious predator, and the design of its circulatory system retains metabolic heat such that its body temperature is often higher than that of the surrounding water (see Carey and Teal 1969; Block and Carey 1985; Carey et al. 1985; Wolf et al. 1988). This "warm-bloodedness" could give the Porbeagle a metabolic advantage over its

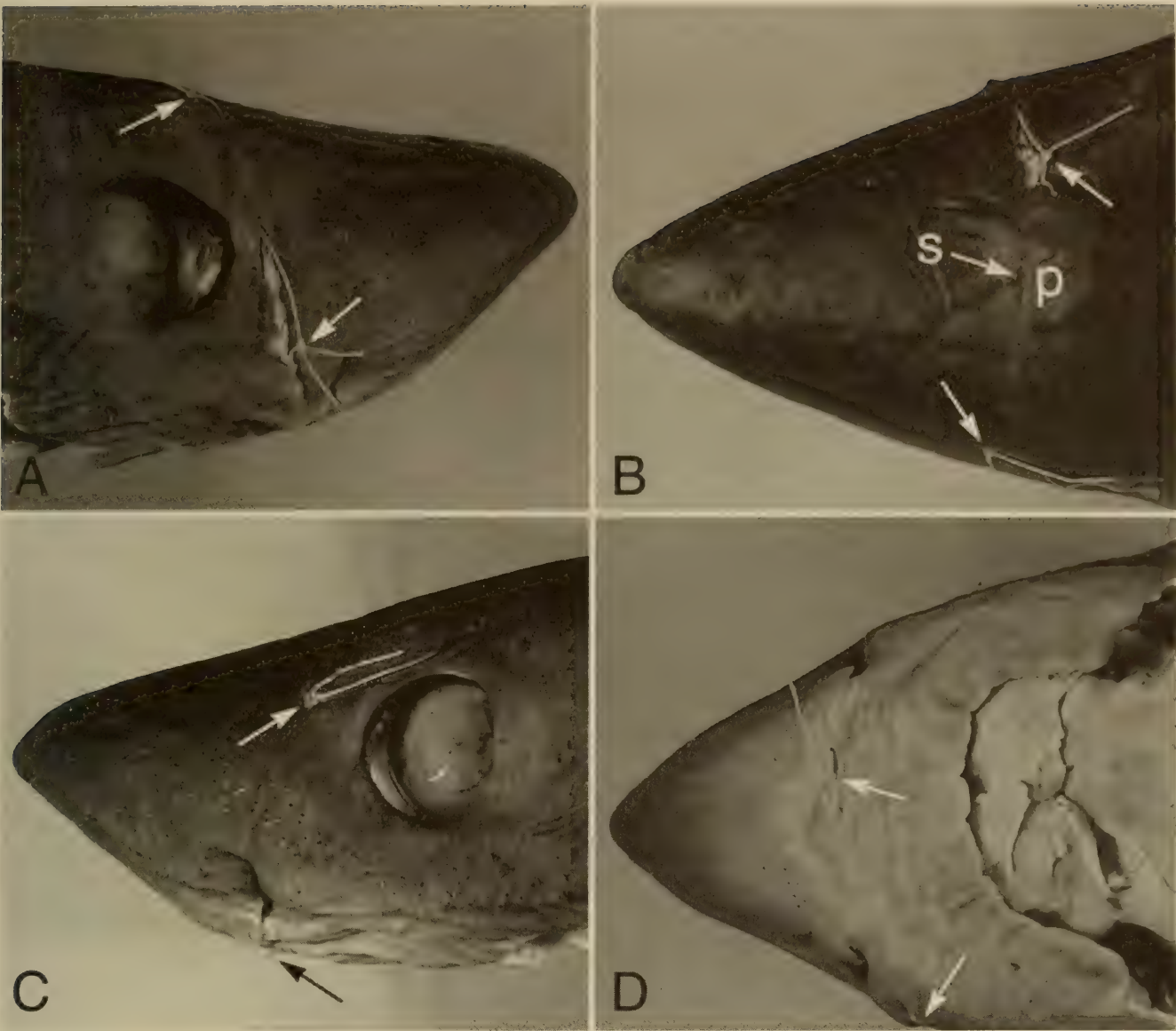


FIGURE 1. Right lateral (A), dorsal (B), left lateral (C), and ventral (D) views of a Porbeagle, *Lamna nasus*, with a gillnet mesh square embedded around its snout. Arrows indicate locations of exposed monofilament knots; s = thin linear scar across pineal window caused by the embedded mesh strand. Pineal window (p) appears as a lightly colored oval region at the dorsal midline of the head. Note that the jaws of this fish were removed prior to taking these photographs.

colder and more sluggish prey — which include mackerels, herrings, cods, and squids (Bigelow and Schroeder 1953; Compagno 1984).

Porbeagles have been fished throughout much of their range (Bigelow and Schroeder 1953; Lineaweaver and Backus 1970; Compagno 1984) and in the northwestern Atlantic they have been the target of a longline fishery since 1961 (Hurley 1997). This fishery is mainly seasonal, March through November, with fishing beginning in early spring on the edge of the Scotian Shelf, followed by movement onto the Shelf itself and then into the Gulf of Saint Lawrence and onto the Grand Banks by July (Hurley 1997). Some fishermen working in late fall have followed the fish back into deeper water (Hurley 1997). Castro et al. (1999) noted that Porbeagle stocks have been depleted within a few years by intensive fisheries

wherever they have existed, but that the species is not currently rare.

In the spring of 1994, AK was aboard the Fishing Vessel *Aquatic Pioneer* collecting biological samples during routine longline operations targeting Porbeagles. On 4 April an unusual Porbeagle was landed while fishing along the Scotian Shelf (42°53' North latitude, 62°53' West longitude). This female, 182 cm in fork length, had a mesh square of monofilament gillnet almost totally embedded in her snout with only the eight corner strands protruding, like so many stout whiskers (Figure 1). The snout of this shark was removed and fixed in 10 percent formalin for later parasitological studies by GWB. The unweighed shark was not noted in AK's detailed deck log as being otherwise abnormal (i.e., thin body, discolored or small liver, sickly looking, etc.).

In the laboratory the "whiskered" snout raised enough interest to initiate a closer inspection, including a histologic examination by JDB.

The net mesh square was 8.25 cm on each side (16.5 cm stretch mesh) and was composed of monofilament nylon 0.6 mm in diameter. The stretched mesh square encircled the snout, coursing from just anterior to the opening of the right orbit (Figure 1A), across the pineal window (Figure 1B), to just anterior to the left orbit and then just posterior to the left external naris (Figure 1C), and finally across the ventral snout anterior to the upper jaw and just posterior to the right external naris (Figure 1D). Only four small portions of the net square remained exposed, each associated with one of the four corner knots (Figure 1). Where the monofilament was embedded, linear scars were visible on the overlying skin surface (Figure 1). Microscopic examination of these scars revealed them to be approximately 2–10 mm wide, consisting of up to 33 rows of placoid scales whose crown ridges were not properly aligned with those of other scales about them. It is likely that they were formed as the lesions caused by the net healed and the placoid scales were haphazardly regenerated. The monofilament was embedded up to 8 mm in places and it resided in the epidermis or more often in the dermis, except along the dorsal midline where it was embedded in the clear tissue of the pineal window (see Figure 1B). The oddly "whiskered" appearance of the fish was created by the two short lengths of monofilament associated with each of the four corner knots that at one time composed portions of an intact gillnet's adjacent mesh squares. Some of the tips of these free lines appeared as if they had been stretched and broken while others looked as if they had been cleanly severed. The location of the mesh square about the snout seemingly would not have permitted this fish to bite these lines. Besides the aforementioned complications, histologic examination of the tunnels within which the mesh square resided revealed a chronic inflammatory and healing response. The inflammation was associated with fragments of granular gray-translucent material, evenly spaced at 5–10 μm intervals, that appeared to be tiny pieces of net material. At first we thought that the regular spacing of these fragments might be explained by them having been carved by the evenly spaced ridges on the crowns of the shark's placoid scales. However, subsequent measurements of the distance between these ridges corroborated the results of Reif (1985) concerning the Porbeagle by revealing the ridges on most head scales to be spaced about 70–80 μm apart. The inflammation about the fragments consisted of macrophages and lymphocytes within necrotic collagen or in perivascular aggregates. The healing response was marked by excessive collagen deposits, i.e., scar tissue, and numerous

elongated fibroblasts in close association with the net fragments. All of the above lesions were localized within the dense collagen layer of superficial dermis, i.e., in the upper stratum compactum.

As mentioned by Jones (1993), although skin lesions have been observed worldwide on a large assemblage of fishes, only scattered reports exist of fish with healing wounds that were caused by net contact. With few exceptions (e.g., see Hampton et al. 1991; Jones 1993), the majority of these reports concerned net contact injuries to various flatfishes (e.g., see Shelton and Wilson 1973; Bucke et al. 1983; Dethlefsen 1990) or salmonids (e.g., see Taylor 1985; Hansen 1988). The healing of teleosts after net contact injuries often consists of scrapes about the head, operculum, and along the trunk as well as lesions on and about fins (e.g., see Sindermann et al. 1978; Jones 1993).

To our knowledge, this is the first report of a healing net contact injury in a shark, and this case is furthermore unusual because it documents a net escapement event resulting in a shark becoming permanently encircled by an almost totally embedded mesh square. Many reports exist of fishes having been permanently encircled by a wide variety of man-made items (e.g., Gudger 1928; Schwartz 1963; Honma 1964). As noted by Overstreet and Lyles (1974), part of the interest in these reports stems from the fact that encircled fishes can sometimes avoid natural predators, capture prey, and otherwise survive even though encirclement can cause severe deformities. Regarding sharks, Overstreet (1978) and Bird (1978) reported on the encirclement of several species of carcharhinids (Carcharhinidae) by box straps. Details provided by Bird (1978) indicated that this type of encirclement can cause significant lesions that may eventually result in death, and although signs of healing were observed, none of the encirclement lesions was fully resolved.

Regarding the present instance it is possible that the Porbeagle tore itself free from a gillnet only to have the remaining mesh square eventually embed itself in its snout as the fish grew larger. It is also possible that a fisherman may have partially untangled and released this toothy fish from a net targeting other species. The literature contains reports of Porbeagles being taken as by-catch in gillnet operations targeting ground fish (Bigelow and Schroeder 1953) and also of these sharks making a mess of nets not meant for them (Lineaweaver and Backus 1970). With adult female Porbeagles commonly reaching 152 to 219 cm in total length and possibly up to 370 cm in total length (Compagno 1984) it is likely that the 182 cm fork length individual reported on here was mature, but still possessed some remaining scope for growth. How or if the embedded mesh square impacted the growth of this fish is unknown. However, its survival and the healing of its net

wound is significant given that net injuries have been shown to lead to an increased susceptibility to viral and bacterial diseases in some fish (e.g., see LeTendre et al. 1972; Dethlefsen 1990). Certainly the Porbeagle reported on here was unlucky, being netted and freed from a net only to later be caught by a longline, and this case may represent a consequence of high fishing pressure in the northwestern Atlantic.

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Hyperthermia Induced Mortality of Gravid Snapping Turtles, *Chelydra serpentina*, and Eggs in a Wood Chip Pile

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de Solla, Shane R., Douglas Campbell, and Christine A. Bishop. 2001. Hyperthermia induced mortality of gravid Snapping Turtles, *Chelydra serpentina*, and eggs in a wood chip pile. *Canadian Field-Naturalist* 115(3): 510–512.

Two gravid female Snapping Turtles (*Chelydra serpentina*) were observed attempting to nest in a composting wood chip pile, on the shoreline of the west end of Coote's Paradise, Hamilton, Ontario, on 7–10 June 1999. Instead of laying eggs, both females buried themselves within the wood chip pile, and were found dead the following day. An autopsy revealed that both females were still gravid, and that the likely cause of death was hyperthermia and dehydration. Four clutches of eggs were also found in the wood chip pile after the cessation of nesting; one clutch was incubated in laboratory conditions but none of the eggs hatched. Subsequent dissection of all of the clutches revealed no development. Subsurface temperatures from the wood chip pile on 10 July 1999 ranged from 28 °C to 60 °C. On 8 August 2000, one clutch was found in the same wood chip pile, in which some eggs successfully hatched when incubated artificially. Artificial compost heaps near nesting sites may pose a risk for nesting turtles, through both adult mortality and reduced hatching success.

Key Words: Snapping Turtle, *Chelydra serpentina*, Hamilton Harbour, composting, mortality, oviposition, wood chip.

Snapping Turtles (*Chelydra serpentina*) nest in a variety of artificial substrates, such as dams, railway and road embankments (Loncke and Obbard 1977), and vegetable gardens (de Solla, unpublished data). In many parts of their range, the majority of females may nest in artificial substrates because natural areas may not be available, and they may travel considerable distances to nest on embankments or dams (Obbard and Brooks 1980). There are no published reports of females dying of causes other than predation and road mortality during oviposition, regardless of the substrate. We report here the death of two gravid Snapping Turtles during a nesting attempt, and the failure of four clutches of eggs, in a composting wood chip pile in Hamilton, Ontario.

Study Site

The turtles were found in a single 6 m × 18 m pile of wood chips located approximately 30 m from the northwestern shoreline of Coote's Paradise, Hamilton, Ontario (43°17' N, 79°53' W), a 90 ha eutrophic wetland at the western end of Hamilton Harbour on Lake Ontario. There is a large population (>400; Galbraith et al. 1988) of Snapping Turtles in this wetland, despite exposure to organochlorine pesticides and other chemicals (Bishop et al. 1998; de Solla et al. 1998).

Along this shoreline, an average of approximately 40 nests has been observed annually from 1986 to 1999 (Bishop and de Solla, unpublished data). Most females nested either in a large community vegetable garden, or in the wood chip pile, although a few females nested in other areas such as grass fields,

embankments, or gravel roads. Snapping Turtles have been observed attempting to nest in the wood chip pile every year from 1986–2000, some of whom successfully deposited eggs. Unlike the nests at the vegetable garden, no occurrences of nest depredation have been observed at the wood chip pile, nor any successfully hatched nests. No deaths of nesting females were detected by the authors, or otherwise reported, from 1986–2000, with the exception of animals run over by motor vehicles or deliberately killed by gardeners.

It is unknown how long the wood chip pile has been present. The last known time an appreciable amount of new material had been added was in 1994. Although the surface and the core of the pile were poorly decomposed, in 1999 there was a layer that extended from approximately 2 cm depth down as deep as 30 cm depth that was well composted and soil-like. Fungi were present throughout and large numbers of invertebrates occurred where conditions were favourable. In 2000, the wood chip pile was much reduced, and was only about half of its size in 1999.

Site Observations

The area was searched for nests for about three to five hours at a time, both in the morning and evening, from 31 May to 2 June 1999, and 5 June to 11 June 1999. The wood chip pile was rarely unobserved for longer than 30 minutes during these times, and often would be under almost continuous observation. On 7 June 1999, at 1950 hrs a large female Snapping Turtle was sighted at the wood chip pile,

and by 2010 hrs was buried within it. At 2050 hrs, she had moved and was buried in a different location in the pile, with her nose and the top of her head exposed. No change in position was seen when observed on 8 June at 0800 and again at 2240 hrs. The ambient air temperature that day reached 31.8 °C. At 0740 hrs on 9 June, the turtle was dug out of the pile and was found to be dead, with the carcass appearing bloated. Eggs were palpable within the abdomen. The body was placed in a freezer at -20°C at approximately 1145 hrs on 9 June.

On 9 June, a second female was found completely buried in the wood chip pile at 0800 hrs, approximately 3m from the location of the first female. Ambient air temperature that day reached 28.5°C. This turtle was partially dug out later that evening, but she was still alive. The first author reburied her in the position in which she was found, with an approximately 10-15 cm thick layer of wood chips covering the carapace. At 2150 hrs, she was still buried in the same position. At 1040 hrs, 10 June she was excavated, found to be dead, and was placed in a freezer at -20°C at approximately 1200 hrs.

Post-Mortem Results

The post-mortem examination of carcasses of both dead turtles were performed at the Canadian Cooperative Wildlife Health Centre (CCWHC) laboratory in Guelph, Ontario, to determine cause of death. Both turtles were kept frozen until the necropsy. The carcasses were thawed at room temperature and a necropsy examination was done on 24 June. Both turtles were in fair body condition, with moderate stores of fat. Turtle A (found dead 9 June 1999) weighed 6.2 kg, with a carapace length of 31.0 cm. The carcass was autolysed. The stomach was empty except for a small quantity of brown fluid. The lungs were congested and the urinary bladder was empty. The uterus was intact and contained 45 calcified eggs.

Turtle B (found dead 10 June 1999) weighed 7.25 kg and had a carapace length of 31.5 cm. The carcass was extremely autolysed with all viscera in a state of advanced decomposition. The uterus had ruptured post-mortem and 54 eggs lay free in the abdominal cavity.

Sections of heart, lung, liver, spleen, kidney, adrenal, brain, skeletal muscle, thyroid, intestine and stomach were taken from Turtle A and fixed in 10% neutral buffered formalin, sectioned for histology and stain with hematoxylin and eosin using routine methods (Luna, 1968). Sections of skeletal muscle, lung and kidney from Turtle B were collected and processed in similar fashion.

Significant histological abnormalities detected in the two turtles included acute multifocal myocardial degeneration in Turtle A and acute degeneration of skeletal muscle myofibres and acute degeneration and mineralization of renal tubular epithelium in

Turtle B. These changes are consistent with dehydration and hyperthermia. In the absence of other significant gross or microscopic lesions, or evidence of infectious disease, it was concluded that death was due to hyperthermia.

Temperature and the fate of clutches

Temperature readings were taken with a mercury stick thermometer on 10 July in the wood chip pile in areas that had the greatest concentrations of turtle tracks and holes excavated by turtles. Readings were taken between 1300 and 1400 hrs on a sunny day, and the air temperature was 27.5°C. Temperature readings were taken at the top of the woodchip pile, 1-2 m above the bottom of the pile (locations 1-5, Table 1), and near the base of the pile, approximately 0.5 m above the bottom of the pile (locations 6-9, Table 1). Unless otherwise noted, each temperature reading was taken at about 10 cm deep in the wood chips, at approximately the depth of the centre of gravity of the turtles that were found dead, and was also the approximate depth of the top of the nests. Temperatures at the top of the pile were appeared to be higher than at the bottom, and the wood chips were drier to the touch than at the base.

Although no more dead turtles were found, one clutch of eggs (N=34) was found and excavated in mid-July. The eggs appeared grossly abnormal with blotchy areas of discoloration. The temperature was 37°C where this clutch was located, and 46°C approximately 20 cm from the clutch at the same depth. The clutch was incubated in a water and vermiculite mixture (1.1:1 mass ratio) at 25°C until late fall; no eggs hatched. There was no evidence of development of the embryos in these eggs, upon dissection.

On 15 October 1999 the wood chip pile was sifted with rakes and three more clutches were found with all the eggs intact. No viable eggs were found, and some eggs had fungal growth on their shells. Internally, only yolk was present with no development of embryos.

TABLE 1. Temperature readings from different locations on the woodchip pile in early July 1999. The depths of the readings were approximately 10 cm from the surface except where otherwise noted.

Top of Woodchip pile	Temp. (°C)	Base of Woodchip pile	Temp. (°C)
1*	42.0	6	35.0
2	45.5	7	28.0
3*	43.0	8	39.0
4	52.5	9	38.0
5 at 10 cm	43.0		
5 at 20 cm	56.0		
5 at 30 cm	62.5		

*Locations where clutches were found.

None of the four clutches had been disturbed and eggs were desiccated in only one clutch. All four clutches were found near the top of the wood chip pile, where both temperature and moisture were greatest.

On 8 August 2000 the wood chip pile was sifted with rakes, and one clutch was found. The wood chip pile was greatly reduced in size compared to 1999, and there appeared to be less well composted material. Although no temperature measurements were taken, the temperature of the compost appeared to be lower than in 1999. One egg from the clutch was already dead and broken, but the rest appeared to be potentially alive. The clutch was used in an unrelated project, and was incubated in a water and vermiculite mixture (1.1:1 mass ratio) at 25°C at the University of Guelph, and a large (but unknown) proportion of the eggs successfully hatched (S. Ashpole, personal communication).

Discussion

Both turtles died in the wood chip pile, without having deposited any eggs. Normally, Snapping Turtles do not bury completely themselves during oviposition, although some turtles that were observed to lay eggs in the wood chip pile had their posterior end lightly covered with wood chips. Thus, the act of burial by the two gravid females was unlikely directly linked to oviposition. There was no apparent effort by the turtles to abandon the nesting attempt and leave the wood chip pile, based upon the available observations of their behaviour. This failure to leave the nest site may have been due to the clinical effects of hyperthermia, to some behavioral cause, or to some other undetected factor.

The temperatures recorded in the wood chip pile in 1999 exceeded the critical thermal maximum for both adults and eggs of this species (Cloudsley-Thompson 1971; Yntema 1976). In this setting, with no method of heat dissipation available, and an additional increment of heat stress due to the muscular exertion of digging, the animals were extremely vulnerable to heat stroke (Simon 1993). Consequences of hyperthermia include cardiovascular failure, metabolic abnormalities and neurological impairment, including stupor (Simon 1993). These effects may be sufficient to account for the turtles' failure to leave the nest site. The removal of some compost from the wood chip pile in 2000 may have reduced the temperature to a sub-lethal level.

High temperatures in the wood chip pile likely make it a reproductive sink for turtles because of clutch failure. Mortality of adult females on the nest is likely a rare event. However, the mortality of adult females would have a much larger effect on the population dynamics of Snapping Turtles than decreased

hatching success (Cunnington and Brooks, 1995). Female Blanding's Turtles (*Emydoidea blandingii*) and Painted Turtles (*Chrysemys picta*) have been seen in the study area, but neither was seen to nest in the pile. Improved success of nesting attempts and a reduced risk of death of adult animals could be achieved by blocking access to the pile during the nesting period.

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A Significant New Record of the Pygmy Shrew, *Sorex hoyi*, on the Montana-Alberta Border

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Hendricks, P. 2001. A significant new record of the Pygmy Shrew, *Sorex hoyi*, on the Montana-Alberta border. *Canadian Field-Naturalist* 115(3): 513-514.

Remains of an adult Pygmy Shrew, *Sorex hoyi*, skull were recovered from a deteriorated raptor pellet on 20 July 2000 at Wild Horse Lake, Hill County, Montana about 2.4 km S of the Montana-Alberta border and 17.7 km WSW of the Montana-Saskatchewan border. Wild Horse Lake is within a large hiatus in the known distribution of this Boreal-Cordilleran shrew species, indicating there is a high probability that a relict population occurs in the immediate vicinity of Wild Horse Lake or in one of the isolated forested uplands (Sweet Grass Hills or Bears Paw Mountains in Montana; Cypress Hills in Alberta-Saskatchewan) in this prairie region.

Key Words: Pygmy Shrew, *Sorex hoyi*, Montana, distribution.

The Pygmy Shrew (*Sorex hoyi*) is widespread across boreal and subarctic North America, with populations also extending south in the United States along the Rocky Mountains in the west and Appalachian Mountains in the east (Long 1974; Diersing 1980; Hall 1981). Although found in a variety of microhabitats (including bogs, marshes and dry grassy clearings), the species generally seems to be associated with mesic forested habitats (Long 1972; van Zyll de Jong 1983) and riparian corridors connected to these. In Montana, the Pygmy Shrew so far has been found in the western Rocky Mountain region near, or west of, the Continental Divide (Foresman 1999) usually in forested habitats, but also in sagebrush-steppe at one collection site.

On 20 July 2000 I found the remains of a Pygmy Shrew skull (intact lower jaw plus upper jaw and skull except the cranium) in a deteriorated raptor pellet at Wild Horse Lake, Hill County, Montana (48°59'N, 110°10'W; 853 m elevation), about 2.4 km S of the Montana-Alberta border and 17.7 km WSW of the Montana-Saskatchewan border, in T37N, R12 E, Sect. 8NENE. The shrew was an adult, based on the degree of tooth wear (K. Foresman, personal communication); M^2 - M^2 breadth (breadth across the second molars) and molariform toothrow length (P^3 - M^3) were 3.81mm and 3.62 mm, respectively. Also in the pellet were the remains of one Meadow Vole (*Microtus pennsylvanicus*).

The area where the skull was retrieved is adjacent to an extensive lakebed depression largely of treeless prairie habitat of a variety of native grassland species (e.g. *Bouteloua gracilis*, *Carex filifolia*, *Koeleria macrantha*, *Poa secunda*, *Stipa comata*), scattered silver sage (*Artemisia cana*), introduced species such as crested wheatgrass (*Agropyron cristatum*), and cropland of wheat (*Triticum aestivum*). The lake basin has experienced several years of drought, supporting no standing water by early summer, but during some years in the early 1990's the lakebed held water and

was surrounded by a lush growth of prairie vegetation (L. Lund personal communication).

The Wild Horse Lake site falls within a large northward hiatus in the known distribution of the Pygmy Shrew, between the known limits in the Rocky Mountains of western Montana and Alberta and the woodlands of eastern North Dakota and South Dakota (Long 1974; Hall 1981). Nearest records (van Zyll de Jong 1983; Smith 1993; Foresman 1999) are Helena, Montana (about 315 km SW), Polebridge, Montana (about 315 km W), near Calgary, Alberta (about 340 km NW), and Swanson, Saskatchewan (about 418 km NE).

Because the Pygmy Shrew skull was found in a raptor pellet, the exact location where the shrew was caught is unknown. The most obvious possibility is that the shrew was captured in the immediate vicinity of Wild Horse Lake in mesic grassy habitat in association with Meadow Voles. However, a migrating raptor could have ejected the pellet containing the shrew skull a considerable distance from where the shrew was captured, depending on the mean daily distance moved and length of the meal to pellet interval.

Little published data is available on daily movements of raptors during migration or their meal to pellet intervals. Schmutz et al. (1996) reported that Swainson's Hawks (*Buteo swainsoni*) traveled straight-line distances of about 190 km/day during southward migration, and Beske (1982) observed juvenile Northern Harriers (*Circus cyaneus*) that moved 14–106 km/day. Both species nest in the vicinity of Wild Horse Lake and the harrier is also a known shrew predator (Bent 1937). However, mean meal to pellet intervals for these two raptor species are not available. For Short-eared Owls (*Asio flammeus*) and Great Horned Owls (*Bubo virginianus*), species also present at Wild Horse Lake and known to feed on shrews and voles, ingested bones of prey take about 10–16 h to be ejected in a pellet (Grimm and Whitehouse 1963, Duke et al. 1976).

Assuming a hypothetical distance of 190 km/day moved during migration, a 10–16 h meal to pellet interval, and a spring/autumn daily diurnal period of 16 h, the Pygmy Shrew could have been carried 119–190 km from where it was caught, if it was consumed immediately in the morning before migration commenced for the day. The above calculated transport distances still leave the Pygmy Shrew found at Wild Horse Lake far removed from the nearest known locations 315–418 km distant; the distance transported during migration could be much less if the shrew was captured by an owl.

Pygmy Shrews are often found in mesic forested habitats (Long 1972; van Zyll de Jong 1983), therefore I suggest that the specimen collected at Wild Horse Lake more likely came from one of the nearby forested uplands, such as the Sweet Grass Hills (about 72 km W), Bears Paw Mountains (about 82 km S), or Cypress Hills (about 65 km N). Relict populations of Pygmy Shrews with little or no gene flow to the Rocky Mountain and boreal populations might persist in one or more of these isolated ranges, as appears to be the case for Dwarf Shrew (*Sorex nanus*) in the Sweet Grass Hills and Bears Paw Mountains (Thompson 1977). My suggestion is supported by limited data on skull measurements. M^2 - M^2 breadth in the Wild Horse Lake specimen was 3.81 mm which is well below the mean value of 3.93 mm for specimens from the Rocky Mountains of Alberta, British Columbia, Montana, and NE Washington (Diersing 1980). M^2 - M^2 breadth was also below the range of values for individuals with equivalent molariform tooththrow length in that sample. The Wild Horse Lake specimen could come from a population with a skull morphology significantly narrower than the main Rocky Mountain population. However, cranial size of shrews is known to diminish in old individuals (Pruitt 1954), and this alone could explain the exceptionally small M^2 - M^2 measurement of the Wild Horse Lake specimen. Clearly, additional systematic sampling for Pygmy Shrews is desirable in the forested uplands of the Sweet Grass Hills, Bears Paw Mountains, and Cypress Hills, as well as at Wild Horse Lake.

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Dave Heilig (NRCS) for promoting the survey. I also thank Kerry Foresman (University of Montana) for verifying my identification of the shrew, determining the age of the animal, and providing the skull measurements. The specimen (MTHP 4280) is now deposited in the Philip L. Wright Zoological Museum, the University of Montana. I benefited from the comments of two anonymous reviewers on an earlier version of this paper.

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Observation of a Golden Eagle, *Aquila chrysaetos*, Attack on a Harlequin Duck, *Histrionicus histrionicus*, in Northern Labrador

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During an aerial survey on the Kingurutik River, northern Labrador, a Golden Eagle (*Aquila chrysaetos*) was observed attacking a female Harlequin Duck (*Histrionicus histrionicus*). Although the attack ended unsuccessfully, we believe this was only a result of disturbance by the presence of the helicopter. We overview previous reports of predation on Harlequin Ducks, and emphasize the need for further research investigating the importance of the influence of predators on populations of Harlequin Ducks.

Key Words: Harlequin Duck, *Histrionicus histrionicus*, Golden Eagle, *Aquila chrysaetos*, predation, Labrador

On 21 June 1999, we conducted a survey for Harlequin Ducks on the Kingurutik River system (57° 0.5' N, 63° 4.0' W) in northern Labrador using a Bell 206L helicopter. This river system is known to hold moderate densities of both Harlequin Ducks and various raptor species (Heath 2001). During this survey, we observed a Golden Eagle, *Aquila chrysaetos*, attacking a female Harlequin Duck, *Histrionicus histrionicus*, in mid-stream. It appeared that the Golden Eagle had captured the female; however, she managed to escape as the Golden Eagle, presumably startled by the helicopter, flew away. We believe that this would have been a successful predation event had the birds not been disturbed. We were unable to determine if the Harlequin Duck had been injured in the encounter; however, this is the first documented interaction between a Golden Eagle and Harlequin Duck.

Current literature on birds of prey as predators of Harlequin Ducks is limited to incidental reports, but indicates that predation can occur on both adults and broods. In Forillon Park, Quebec, Brodeur et al. (1998) located two adult female Harlequin Ducks (carrying satellite radios) killed and consumed by a Red-tailed Hawk (*Buteo jamaicensis*) and Great Horned Owl (*Bubo virginianus*). In Hebron Fiord, northern Labrador, a white-phase Gyrfalcon (*Falco rusticolus*) was observed circling and stooping on two adult female Harlequin Ducks (Rodway et al. 2000); however, the females avoided capture by diving (J. Gosse, personal communication). Bald Eagles (*Haliaeetus leucocephalus*) have been reported as a threat on both breeding and winter grounds (Dzinbal 1982; McEneaney 1997; Robertson and Goudie 1999). Smith (2000*) reports that 10 of 13 predation

events on ducklings were most likely by raptors (4 by Red-tailed Hawk, 1 by Northern Goshawk *Accipiter gentilis*, 1 by unknown Owl spp., and 4 by unknown raptor spp.), and that fledging by Harlequin Ducks coincided with high numbers of raptors and their fledged young. Raven (*Corvus corax*), Arctic Skua (*Stercorarius parasiticus*) and several mammalian predators including Mink (*Mustela vison*), Marten (*Martes americana*) and Arctic Fox (*Alopex lagopus*) have also been identified as potential predators during the breeding season (Bengtson 1966, 1972, Kuchell 1977, Bruner 1997, Smith 2000*) and numerous Mink attacks have been observed on Harlequin Duck broods in southern Labrador (K. Squires and R. I. Goudie, personal communication).

Despite these incidental reports, the influence of predation on breeding populations of Harlequin Ducks has yet to be addressed in the literature (but see Heath 2001 and forthcoming publications). Previous studies have emphasized that Harlequin Ducks may be primarily limited by prey availability on the breeding grounds (Bengtson and Ulfstrand 1971; Gardarsson and Einarsson 1994; Rodway 1998); however, the growing list of direct predation encounters suggests that the role of predation should receive further attention.

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*See Documents Cited Section

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A Remembrance of John Clifton Ward, 1921–1999

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Flook, Donald R., and Joseph E. Bryant. 2001. A remembrance of John Clifton Ward, 1921–1999. *Canadian Field-Naturalist* 115(3): 517–519.

John Clifton Ward (Clift) was born 10 January 1921 in Sexsmith, Alberta, and died 21 November 1999 in Victoria, British Columbia. He was predeceased by his sisters Hazel McCann and Lona Waite, and his step-son Cleve. Mourning his passing are his wife, B.J., now living in Courtenay, British Columbia, his sons Scott in Canmore, Alberta, and Dean in Chesterville, Ontario, and step-daughter Cori-Lee in Victoria and their families including nine grandchildren.

Clift assumed responsibility early. He was only 7 years old when his father died and 13 when his mother died. He and his sisters, both older, helped each other while he lived with them first in Grand Prairie and then in Hythe, Alberta, where he completed high school. He joined the RCAF in 1940 at 19 years of age and served overseas.

On his discharge in 1945 he enrolled at the University of Alberta and received his B.Sc. in zoology in 1949. He had an excellent undergraduate record and went on to complete an M. Sc. in zoology in 1951, also at the University of Alberta. He specialized in Fisheries Management and Conservation under Dr. R. B. Miller. His thesis was on the biology of Arctic Grayling in the southern Athabasca drainage. (Ward 1951*)

Clift joined the Canadian Wildlife Service in 1951 with the title of “Limnologist,” to work as an advisor to the National Parks Service, later named Parks Canada. He continued in that role until he retired in 1976. During his career he was headquartered sequentially in Ottawa, Banff, Edmonton, Jasper, Calgary, Ottawa, and finally in Edmonton from where he retired.

Clift was a kind and modest man. He loved his work and counted his co-workers among his best friends. He worked closely with park wardens and the relationship was mutually helpful. Clift was pleased to pass along his knowledge of fish and limnology and gratefully acknowledged information provided by wardens from their field observations. Wardens were always ready to help him with field projects and he was a favourite lecturer at the warden’s training schools where he frequently instructed.

The official role of the Canadian Wildlife Service



Cliff Ward in retirement, 1982, Victoria, British Columbia. Photographer: Master Portriature of Victoria, British Columbia.

in the National Parks was advisory to Parks Canada but during the period when Clift was assigned to the mountain parks he was called upon, because of his expertise, to oversee fish hatchery operations and to perform hands-on supervision of stocking and other fish management activities. That program contributed greatly to angling opportunities in the parks.

When trout hatcheries in Waterton Lakes and Banff National Parks were closed the production of trout for stocking in the mountain parks was concentrated in Jasper. Clift devoted considerable attention to improving trout culturing methods and water supply at the Jasper hatchery (Ward 1962d; Ward and Cuerrier 1967a; Ward 1969a*). Under Clift’s guidance the hatchery became a popular destination

among park visitors and he encouraged its use to inform the public about the aquatic environment (Ward and Cuerrier 1967a; Ward 1972a*). In retirement Clift met several people who spoke warmly of visits they had made to the Jasper trout hatchery. On one occasion when he was working on the British Columbia Ferry between Vancouver and Victoria a group of tourists from Arkansas recognized him from a visit to the Jasper hatchery. The hatchery had been the highlight of their trip to Jasper and for the rest of the voyage they and Clift discussed the hatchery in great detail.

Clift and Jean-Paul Cuerrier of the Canadian Wildlife Service pioneered a technique of transporting live trout anaesthetized and sealed in plastic bags filled with pure oxygen and a small amount of water and cooled by ice in separate containers (Ward 1958, 1962c; Ward and Cuerrier 1967c). The method was used successfully in National Park projects to transport live trout by plane, train, truck and packhorse. Survival was high and in contrast to tank transport no heavy equipment and much less water were required. The method has been used widely in trout management.

Clift and his colleagues experimented with other innovative techniques. They oxygenated ice-covered lakes by pumping air or water in order to prevent winter kill of fish (Ward and Kooyman 1967b). They also tested the effects of toxicants applied to lakes to kill non-game fish in order to reduce predation on or competition with trout (Ward 1962a; Ward and Cuerrier 1967d). Clift also participated in a project in which television was used to observe conditions on the bottom of a deep lake.

Clift evaluated experimental plantings in the mountain parks of some salmonid species not native to those parks (Ward 1962b, 1962c, 1974c*; Ward and Cuerrier 1967b; Ward and Kooyman 1967a). Species with which he experimented were: Atlantic salmon, Quebec red trout, golden trout, and splake, the latter a fertile hybrid of Lake Trout and Eastern Brook Trout developed in 1946 by J. E. Stenton, Park Warden in Banff. Among those plantings, only the splake established naturally reproducing populations and they did so in two lakes. Because splake exhibited good survival, growth, longevity and sporting characteristics, they were also maintained for a number of years by repeated plantings in some lakes where they did not reproduce.

The emergence of ecological awareness in the Canadian public that began in the late 1960s led to

changes in the philosophy and policies of Parks Canada. By the early 1970s the priority for management of park waters had shifted from enhancement of angling to preservation of aquatic ecosystems. Clift responded by undertaking comprehensive basic limnological inventories of Pukaskwa National Park, Ontario (Ward 1972b*, 1974b*, 1975c*) and La Mauricie National Park, Quebec (Ward 1975a*), writing his major report on the fishes of the mountain parks (Ward 1974c*), and performing other limnological investigations all with the same high degree of dedication and professionalism as he had exhibited in his earlier projects to enhance angling.

By combining his 25 years of service with the federal government and his five years of service overseas in World War II, Clift was able to retire on full pension at the age of 55. "Retirement" did not mean an arm chair in front of the fire. All his life Clift had practised a broad variety of "extra curricular" activities, including such things as hooking magnificent huge rugs. Retirement simply allowed more time to devote to his broad span of interests. First came a couple of courses in geology at Cariboo College in Kamloops, B.C. to increase the excitement of the extensive rock hounding and gold panning that he and his wife undertook all over B.C. He and his wife also served for four years on B.C. Ferries where Clift obtained Life Boat Certification for International Waters and, with an Industrial First Aid Certificate, became a First Aid Officer. To keep things active, Clift and his wife built a beautiful modern home on Salt Spring Island and a few years later another on Vancouver Island near Duncan. During some of their years at Duncan they operated the "JoyClift Coffee Stop" where Clift became locally famous as "the best muffin maker on the Island." Unfortunately, Alzheimer's disease gradually took over and Clift and his wife moved to Victoria to be closer to appropriate medical services. Eventually this bright, active and all-round great guy succumbed to the ravages of the disease — a very sad ending to a productive and happy life.

Acknowledgments

We thank the librarians at the Environment Canada libraries, especially Jean-François Bélanger in Ottawa, Susan Blackman in Edmonton and Deborah Lister in Calgary for their assistance in locating the unpublished reports and we greatly appreciate the assistance of Clift's widow, B. J. Ward, in the preparation of this remembrance.

Publications and Selected Unpublished Documents by J. Clifton Ward

Much of Clift's work was not published but was presented in manuscript reports that are deposited in the libraries of Environment Canada in Ottawa and Edmonton and Parks Canada in Calgary. We hope that the following listing of his published papers and unpublished reports will make them better known and increase their use as sources of valuable baseline information.

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Book Reviews

ZOOLOGY

Cuckoos, Cowbirds and Other Cheats

By N. B. Davies. 2000. T and A. D. Poyser, London, UK. ix + 310 pp., illus.

As a lad I frequently heard the bizarre tale of the (Common) Cuckoo. This tale was a relatively new discovery that lent itself to wiles of the photographer. With the arrival of television, the struggles of the juvenile Cuckoo were just the fodder for the newly created BBC's nature shows. Images of the tiny cuckoo baby's struggles with its host's young were just what this new medium wanted. So I thought I knew this narrative well. I was wrong. This piece of biological history involves more cunning and deceit than most of us could ever imagine.

Nicholas Davies describes in great detail the well-studied life of the Common Cuckoo. This Eurasian bird has developed some remarkable tactics to live its life as a parasite. How it has achieved these strategies, why it has adopted this way of life and the response of the host victim are the major questions researched by the author. He analyses experiments he and others performed to test hypotheses proposed to explain each segment of behaviour. He is very careful not to jump at the most obvious explanation, but to lay out all possibilities. He then examines these possibilities in light of logic and the observed facts. The result is an insight into a world of intrigue, betrayal, fakery, deception, and success on the part of the cuckoo. The hosts retaliate with rejection, abandonment and, finally, acceptance, when acceptance is the more productive tactic.

The author then repeats his study for Great Spotted, Diederik, and Bronze cuckoos in the Old World. For the New World he looks at the cowbird clan, especially the abundant Brown-headed Cowbird. In the case of the latter, he outlines how our human activities have benefited the cowbird at the expense of other species, and that their current abundance and the problems they create are primarily our fault.

For each species the author examines in detail the strategy that each bird uses to ensure success for its parasitic lifestyle. In fact, it involves just as much work, more stealth and speed and often considerably more bravery to be a parasite than to raise a brood of one's own. Davies looks at the reasons why some species adopt this approach and reviews the advantages and disadvantages. Not surprisingly there are added benefits both to the individual and to the species for parasitism. There is also a point where it is more productive for the host to accept parasitism.

Naturally hosts that have been parasitised for ages have developed defense strategies.

So far Davies has dealt with the "classical" parasites, birds that lay eggs in other species' nests. There are however many more cases of parasitism amongst birds than I ever thought possible. I did remember reading of Wood Ducks and goldeneyes behaving parasitically, but never dreamed that swallows and Starlings, Moorhens and Coots are included in the avian freeloaders. Finding parasitic eggs that are laid by the same species has proven very difficult. Researchers have had to be innovative just to become aware of the possibility. It still seems hard to believe that a bird like a Cliff Swallow has been videotaped zipping next door to throw out her neighbour's egg and replace it with one of her own.

The author has added a final chapter on brood parasitism in other animals. The examples range from the bizarre Lake Tanganyika catfish, an obligate parasite on cichlid mouthbreeders, to the demonical slave-owning ants.

The book is illustrated with line drawings by David Quinn and with both black-and-white and coloured photographs. Quinn's drawings are first rate, showing accurate attitude, body shape, and fine detail while being gently artistic. Sadly the only two coloured illustrations by Quinn are on the dust cover. A few of Quinn's colour plates inside the text would add much charm to this book. The photographs are good quality and very illustrative.

The author's writing style is clear and informative and this is an easy book to read. My sole criticism is that he repeats some of his key findings rather too often. I was also surprised that he used Hispaniola instead of the Dominican Republic and Haiti until I learned that that is still the name of the island itself.

This is a book that should interest all naturalists. In many ways it reads as much like a detective story as a biology text. The parasites are a devious bunch and the author and his fellow researchers have had to be really creative with their methods of discovering and chronicling their strategies. I'm sure Agatha Christie would have been fascinated.

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The Nature of Hummingbirds: Rainbows on Wings

By Harry Thurston. 1999. Greystone Books, Vancouver/Toronto. 112 pp., illus. \$34.95.

Everyone who knows them loves hummingbirds. Tiny, beautiful, and feisty, they seem too fragile to be real. This author has captured their appeal both in words and stunning photographs, and hummingbird lovers can learn a great deal from the detailed professional text. They are the second-largest family (Apodiformes) in the Western Hemisphere and are closely related to swifts. They breed from Alaska to Terra del Fuego. Of the 320 species (which are found exclusively in the Americas) only the Ruby-throated spends the summer in eastern Canada, although occasionally a vagrant of another species will stray east. The Rufous is common in British Columbia, and a growing number of Anna's are found in Vancouver, Victoria, and environs, some even over-wintering at well maintained feeders. The Bee hummingbird is the smallest bird in the world at 6.25 cm but you will have to go to Cuba to see that one.

The text strikes a good balance between science and description of every aspect of their lives, and much of it is hard to believe: 1260 heartbeats and 250 breaths per minute; a thimble-sized nest, bound with spider web; raisin-sized eggs; a migration of 2500 km from the Canadian west coast to Mexico; a migration stage flight of 1000 km on 2 g of fat; a wingbeat of 80 times per second, sometimes rising

to 200. To help accomplish these feats, they have two extra pairs of ribs and an enlarged sternum. Since they have very little insulating down, they can reduce their body temperature from 97.5° F to 53.5° F to conserve heat overnight. Their metabolism is so efficient that we would have to eat half our weight in sugar to metabolize food at the same rate, but there would not be enough flowers to feed us in any case - nor would we be able to fly. Hummingbirds prefer to drink nectar from flowers, which is high sucrose and low fructose. Because the nectar is at the base of a tubular flower — not always red, but purple and blue as well — the flowers on which they feed have evolved for bird pollination and most of them exclude bees or butterflies as pollinators, but the hummingbirds are adaptive and eat insects if necessary. Unlike many other species, Hummingbird populations are healthy, partly because their fledging rate is higher than most birds — between 20 and 50%, and perhaps partly because they are impossible for predators to catch when flying.

This is a beautiful book with a good deal of serious scientific information about a bird which thrills many people. If you have a passion for hummingbirds, this is for you.

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Albatrosses

By W.L.N. Tickell. 2000. Yale University Press, New Haven and London. 448 pp., illus. + 52 plates. U.S.\$60.

It was a pleasant surprise to find there is a wealth of knowledge on albatrosses. I have often been dismayed to read of our lack of knowledge for some even relatively common birds. On reflection, I realized albatrosses nest on open, vegetation-free headlands and islands in large colonies rather than scattered in deep woods or dense wetlands. This means counting nests and observing behaviour is simply a question of devoted work. Getting to the colony, however, can be quite a task. The weather too can be irksome; two researchers we met recently had endured two weeks of rain (on Albatross Island, South Georgia). Nevertheless, there are good data sets for most of the world's albatross. Now this information is accumulated into a single volume.

So if you want to know the details of the land-based portion of an albatross's life this is the book for you. The author avoids the issue of species definition and treats each population separately. This way it is not an issue whether the birds are split or lumped in the future. For example, the Black-browed

Albatross and the Campbell Island Black-browed Albatross (from Campbell Island, naturally) are listed separately.

The book begins with information on the albatrosses' habitat. There are some fine descriptions of the southern, equatorial Pacific and north Pacific oceans themselves, in terms of current and winds that affect albatross. The portrayal of the relevant islands includes a location and description and provides a history of the voyages of discovery (mostly from a European perspective). These fine birds were exploited for the feathers, quills, meat, and oil as soon as these islands became known. They were even used as target practice. Friends of humans such as rats, cats, and pigs, ravaged their islands. Mother Nature added storms, tempests, ice, and volcanic eruptions. Now albatrosses face the perils imposed by longlining for tuna. Despite all these desecrations we still have these aristocratic birds gracing the oceans skies.

The author organizes the birds into three groups; southern, tropical, and northern albatrosses. He presents an organized compilation of all the information

he could gather on each species. This includes anecdotal evidence from voyagers, particularly from the early years, as well as more structured scientific studies. The most recent studies use electrical, radio, and satellite detectors to give some information on the birds' activities away from the nest.

While the author devotes considerable attention to the bird's breeding history I found the information on geographic distribution of more immediate use. The island location is given for each colony and the colony positions are pinpointed on each island. An appendix gives the size of the population over the years for which data are available. This enabled me to compare my own estimates with more rigorously conducted counts. Typically my assessments were very low. This was truer where the terrain was rocky and birds could be hidden from the viewer. These chapters also contained information on albatross habits that challenged long held beliefs. Wandering Albatross that were tracked by satellite did not go around and around the world but made a series of erratic zigzags to and from feeding areas. Albatross do not always nest on the windy side of the island. Another interesting aspect of albatross behaviour is their partition of the sea's food resources. While they all feed on fish, krill, and squid, they do so in a way that reduces unwarranted competition.

The writer includes a fascinating chapter on albatross flight. They are such impressive, graceful birds on the wing that you are forced to wonder how they do it. The author has summarized what is known (or

speculated) so far. In reality a little magic still remains in the albatross's flying skill. The following chapter on behaviour absorbed me less. Not that albatross behaviour is dull; far from it. I admit I have given descriptions of some incidences of behaviour in similar terms to the author. Reading about behaviour, even with neat line drawings is, however, a bit dry.

A little more unusual in a book of this type is a chapter on the poetry written about the albatross. I was surprised to learn that Samuel Taylor Coleridge who wrote the classic "Rime of the Ancient Mariner" never saw an albatross. Such is the romance of these birds.

This book will be primarily of interest to scientists and the more serious visitors to albatross islands. It is written in a scholarly style, but is easily read by the non-scientist. The text is well supported by numerous charts, graphs, maps, tables, and drawings. There are several black-and-white photos, including some taken in the late 1800s, scattered throughout the text and a special section of modern, high-quality colour photos at the back. The 21-page bibliography must contain over 1000 references. This book is a good reference source for both naturalists and historians.

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2193 Emard Crescent, Beacon Hill North, Gloucester, Ontario K1J 6K5 Canada

The Nature of Frogs: Amphibians With Attitude

By Harry Parsons. 2000. Douglas & McIntyre Publishing Group, Vancouver. x + 102 pp., illus., Cloth \$34.95; paper \$24.95.

One of the perennial questions in conservation is how to inoculate the unenlightened with a passion for biophilia. Gesticulating one's arms wildly while effusing about the endearing qualities of a particular species rarely is an effective strategy. For the most part people need an emotional connection to something before they can embrace it more intellectually. Books lavishly endowed with colour photographs are one way to try and capture the hearts and minds of people and *The Nature of Frogs* succeeds admirably well at this task.

Almost every other page of the book is devoted to a full-page, colour photograph. Not surprisingly, many of the photos are of colourful tropical species, but in addition many North American species are featured. Photos are also used to illustrate various activities (e.g. calling, amplexus, feeding) as well as life stages (e.g. egg mass and tadpoles). The images are crisp, the colours are rich and the quality of the photos ranges from good to exceptional.

The accompanying text provides a broad introduction to frogs, but of necessity it skims over most topics. The text is divided into five chapters. "Consider the Frog" introduces amphibians, frogs and the major groups. "Kermit and the Devil" deals with the role of frogs in human societies. Reproduction and the anuran life cycle are examined in "A Frog He Did A-Wooing Go." "Food or Foe" deals with frogs as predators and prey. The last chapter, "The Future of the Order Anura" discusses amphibian decline.

The text is filled with many little gems. For example, according to Parsons the Egyptian hieroglyph for 100 000 is a tadpole. Readers are also introduced to the Paradoxical Frog (*Pseudis paradoxa*) whose tadpoles are larger than the adult. Inevitably, with so many examples mentioned in such a short text, the reader is left wanting to know more about particular topics. According to Parsons there are tropical bats which specialize on frogs, but no other detail is provided. On rare occasions, the text becomes little more than a list: one short paragraph covers cultural

roles of frogs in Nepal, Korea, Vietnam, Australia, and New Zealand. For the most part, Parsons has skillfully skimmed the highlights of anuran biology, weaving his own experiences into the text, adding a personal touch to the many topics. Equally important, his passion for frogs and his concern for their survival is evident throughout the text. It's hard to

imagine anyone reading this book and not coming away smitten with frogs.

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Gatherings of Angels: Migrating Birds and their Ecology

Edited by Kenneth P. Able. 1999. Cornell University Press, Ithaca, New York. 193 pp., illus. U.S.\$29.95.

Perhaps once every five years I read a book that presents scientific facts in such a rivetting way that one wonders why other writers fall so far short. Able offers such a winning formula. His book provides insight into the complexities of bird migration, one of the most "extraordinary of natural spectacles."

Ken Able, a biology professor at the State University of New York, Albany, has devoted his life to the study of bird migration. He has contributed two introductory chapters and one concluding chapter, together with a short essay to introduce each of the other chapters: two on trans-gulf migration and six about migrations of eight bird species, the Rufous Hummingbird, Blackpoll Warbler, Broad-winged Hawk, Sandhill Crane, White-rumped and Baird's Sandpipers, Dunlin and Western Sandpiper.

Readers cannot help but be impressed by the "immensity, elegance and inherent risk that attend the great migrations" described by Able and his eight collaborators. For some species, challenges to a species' survival may be greater during migration than on either the breeding or wintering grounds. To understand the complex, multi-factorial, interacting pressures that weigh on the survival of each individual migrating bird it is "critical to keep a clear view of what we know, ... the degree of certainty with which we know it, and the inferences that can confidently be made." Nor should we, Able suggests, "rely too heavily on strictly economic arguments," for this dooms us to "the bean counter's dilemma — knowing the cost of everything but the value of nothing."

Radar studies have helped to confirm that Blackpoll Warblers, after building up body fat in Massachusetts, wait for a cold front and then fly over ocean for about 85 hours, passing over Bermuda, and not landing until they reach Northern South America; the hazardous but largely predator-free trans-oceanic route is 1500 miles shorter than the land route via Florida. Flocks of Broad-winged Hawks time their migrations to take advantage of topography and sunny

days to soar, with low energy consumption, 80% of the way to Colombia. Near the Platte River in Nebraska about 500 000 Sandhill Cranes during each spring migration benefit from the 6 to 8% of corn kernels left in fields after harvest; they gain sufficient fat there to aid their reproduction when they reach their breeding grounds farther north. After putting on fat at Cheyenne Bottoms, Kansas, and a non-stop flight of 2000 miles from there to the arctic breeding ground, White-rumped Sandpipers lay four eggs equal to 90% of the female's body weight. Two species arrive in the Cooper River Delta of Alaska with their energy reserves depleted: the long beak of the Dunlin gives it access to tiny clams deep in the mud, with which it can satisfy its energy needs in a few hours; the smaller Western Sandpiper, in contrast, must feed almost continuously to satisfy itself. In terms of body lengths (almost 49 million), the Rufous Hummingbird makes what is relatively the longest migration of any bird, in spring up the Pacific coast from central Mexico as far as Alaska, and in fall down the alpine meadows of the Coast Range or the Rocky Mountains; nectar from flowers may increase their body mass from 2.7 g to 5.7 g, but to get it they must hover, the most energy-intensive form of flight.

Each chapter is illustrated with appropriate photos and each migration is illustrated by a superb map. It is a treat to read a book that is coherent, understandable, and almost free from mathematical formulae, with each chapter written by a single author. Complicated scientific hypotheses are distilled into understandable English, reminiscent of the prose of men like P. A. Taverner and A. C. Bent in the first half of the 20th century. What a striking contrast to the typical heavy, overwhelmingly scientific ("technospeak") papers in some ornithology journals today! I recommend this book to *everyone* with an interest in birds.

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Kingbird Highway: The Story of a Natural Obsession that Got a Little Out of Hand

Kenn Kaufman. 2000. Mariner Book, Houghton Mifflin, Boston MA. Paperback. 318 pp., illus. U.S.\$13.00.

The gestation period of a book is said to be longer than that of an elephant (up to 22 months). This book is another example; he wrote the first draft in 1975, resurrected it in 1990, obtained help from skilful editors, and finally published the hard-cover edition in 1997. Three years later it was re-issued as an inexpensive paperback, the subject of this review.

Keen birders recognize Kaufman as one of the top authorities on bird identification. The first six chapters of *Kingbird Highway* tell how he got his start.

In 1973, after completing high school in Wichita, Kansas, Kaufman determined that he would set a new North American record for the number of bird species seen in a year. Guy Emerson of the National Audubon Society had been the first; he identified 497 species in 1939, followed by Bob Smart with 510 species in 1952, Roger Tory Peterson (accompanied much of the way by James Fisher) with 572 in 1953, Stuart Keith with 598 in 1956, and Ted Parker with 626 in 1971. Kaufman determined to spend 1973 surpassing the Parker record; this quest occupies the last 20 chapters. To run up a large total for the United States and Canada, Kaufman had, like his predecessors, to crisscross North America from California to the Florida Keys, to Gambell Island off the western coast of Alaska. Unlike his predecessors, he made his trips by hitch-hiking.

The previous year, 1972, had seen Richard Stallcup edge out Richard Webster, for the largest California-only list, 428 species to 427. Kaufman was aiming higher, for a United States and Canada list of 635 or 640. By 26 January he had ticked off his 200th species for the year, somewhat ahead of his expectations. Yet he was somewhat non-plussed two days later in Portsmouth, New Hampshire, to meet Floyd Murdoch, on an identical quest. Murdoch was researching the history of the National Wildlife Refuges, and in visiting each was certain to gain a large list. Now Kaufman had a competitor, not merely a number to surpass.

Some destinations were for a specific purpose, such as San Juan island off the Washington coast, to see the Skylark. From there he went back to the Florida Keys. Who should be with him on a boat trip to the Dry Tortugas but Floyd Murdoch, whose year list by then was about 50 species behind Kaufman's 440.

Kaufman shares with us the travails of hitch-hiking, including days without food and being wet for several days in succession. He travelled light, but met some of the keenest birders on the continent, including Ted Parker and the author-artist, Roger Tory Peterson, guest speaker at the first-ever convention of the newly formed American Birding Association in Kenmare, North Dakota in June. Kaufman's year-to-date tally was 575. He then

hitched a ride straight through from near Whitehorse, Yukon, to Fairbanks, Alaska. He passed the Parker record of 626 in late July, had a total of 630 when he hitched his way back to New Jersey in August, and 640 when he reached El Paso, Texas. Persuaded to take a holiday from his quest, Kaufman spent late August in Mexico with Ted Parker and two friends in search of the Eared Trogan.

Now he had four months to go. The species not yet on his list were widely scattered. A phone message concerning a Spotted Redshank at Brigantine Refuge, New Jersey, sent Kaufman hitch-hiking 2500 miles in the rain in five days. When he got there, he saw the bird in question, already viewed by a thousand or more birders, all of whom had ticked off Spotted Redshank. But a shock awaited him. Harold Axtell, an acknowledged expert, had been to see the bird and two days earlier had written a full page description of it pointing out that it was merely a Greater Yellowlegs stained by oil.

This long and futile trip to see a single species that was not as advertised, was a turning point in Kaufman's life. He realised that in future he must learn the skills that Axtell had developed over a lifetime of study and that "long-distance hitching ... was hypnotically mindless." Another trip across the continent to Seattle gained him a Sharp-tailed Sandpiper, then he took work picking apples in a Washington orchard to earn money. With him on a Westport boat trip on 7 October was his friendly competitor, Floyd Murdoch, who was now several species ahead. Kaufman hitched to Oklahoma to add the Lesser Prairie-Chicken, but he was slowing down. He took another trip into Mexico, outside the area of his list. In December he took part in the Christmas Bird Counts at Phoenix, and in the Yuma count added a Black Rail and the first-ever Rufous-backed Robin recorded in California. Then at Freeport, Texas, on the final CBC of the year, he fell off the breakwater rocks and nearly drowned, losing the precious telescope loaned him by Edgar Kincaid.

During 1973 Kaufman had thumbed his way 69 000 miles, paying only for a few short boat trips and the flight to Kimball Island. On 31 December he did not yet know that Floyd Murdoch had edged him by 669 species to his 666. Participating in a field sport that "had few fans, no professionals and no referees," Kaufman had come to the realization that "list-chasing was not the best way to learn birds," though it had been "an incentive for getting to a lot of places." And unequivocally he had set a record that would likely never be broken, "the most birds for a buck." His total living and travelling expenses for the year had come to less than \$1000.

This book is a travelogue that tells of interesting birds in fascinating places, watched by idiosyncratic people, some of them "big names," (Stuart Keith, Jim

Tucker, Guy McCaskie, Harold Axtell, and Victor Emanuel, to name but a few). Though listing of new species eventually becomes humdrum, this book would make a good present for any fanatic birder of your acquaintance, whether or not that person is familiar with the term IDIOT (Incredible Distances In

Ornithological Travel), introduced to us with Kaufman's quiet humour.

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Reproductive Biology of Bats

Edited by Elizabeth G. Crichton, and Philip H. Krutzsch.
2000. Academic Press, San Diego. xi + 510 pp., illus.
U.S. \$99.95.

This edited volume brings together 16 researchers summarizing 11 specific topics on the reproductive biology of bats. Although there are general reviews and works on various aspects, there is no single comprehensive source that compiles the full breadth of biological knowledge of bat reproduction. In terms of extant species and global distributions, bats are the second most successful group of mammals, next to rodents. The reproductive potential of bats is considered constrained, however, with typically one young produced only once or twice per year. This deficiency is compensated by a diverse array of reproductive strategies that have benefited them in radiating to most environments throughout the world. But to understand and study the unique and fascinating mechanisms employed by bats and their associated life history traits is difficult but challenging because of their small size, nocturnal behaviour, and ability to fly.

The first three contributions deal with endocrine control of reproduction in bats. These cover the interactions of the hypothalamic-pituitary complex (written by E. L. P. Anthony), circulating gonadal hormones (L. Martin and R. T. F. Bernard), and peripheral endocrines (G. G. Kwiecinski and D. A. Damassa). At present, the current state of knowledge of bat endocrinology is considered in its infancy. As knowledge on the captive breeding of bat colonies improves, increased breadth in experimental design will shift research from the accumulation of baseline data to an emphasis on the role and mechanisms of reproductive hormones.

Two chapters are devoted to the morphology and physiology specific to the male (P. H. Krutzsch) and female (J. J. Rasweiler, IV and N. K. Badwaik) reproductive tract of bats. More so than other groups of mammals, bats have a higher frequency of anatomical asymmetry such as dominance of one ovary. The adaptive significance of this may be to avoid more than one young per litter. There is a limit to the amount of extra weight that a pregnant female can carry while maintaining flight and con-

tinuing to forage, a size constraint worthy of in-depth study in relation to reproductive form and function. Pregnancy (N. K. Badwaik and J. J. Rasweiler, IV) is also thoroughly discussed including preimplantation development, implantation of the blastocyst, and development of placental organs and foetal membranes.

Male activity patterns in bats are usually closely synchronized to female reproductive cyclicality. Reproduction seems to be timed so that lactation, the most energetically expensive part of reproduction, occurs during the peak of food availability. This can be facilitated by sperm storage, a subject covered by E. G. Crichton, and a phenomenon unique in bats because of the extended time intervals involved. Considering the potential benefits of sperm preservation in humans and domesticated animals, research into the mechanisms and physiology in bats is an area of study deserving attention.

There is an overview of life history traits and reproductive strategies of bats (P. A. Racey and A. C. Entwistle). Topics include seasonality and reproductive patterns, reproductive delays and their adaptive significance, and the limits of reproduction. A complementary paper discusses the effects of environmental regulation on the reproductive ecology of bats (P. D. Heideman). Separate chapters also deal with mating systems in bats (G. F. McCracken and G. S. Wilkinson), and parental care and postnatal growth (T. H. Kunz and W. R. Hood).

The content ranged nicely from general reviews to more specific in-depth studies; however, I thought the order of chapters could have been better organized. Reproductive strategies and environmental regulation, two chapters near the end, would have been good introductory discussions for the book. This would have given a firm basis to the more specialized sections dealing with endocrine control, which were presented first, but the chapters are nonetheless independent works of study. One apparent editorial oversight is the absence of references for literature cited in the preface. Overall, the information is attractively presented with each

chapter having a table of contents, appropriate headings and subheadings, discussion or summary, and extensive up-to-date references. However, based on content and price, the book is definitely geared to the professional bat researcher as opposed to the amateur bat naturalist. It will be the source to consult for years to come on reproductive biology of bats. Not only is it a summary of the current

state of knowledge, but areas in need of research are also identified.

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BOTANY

Phycology

By R. E. Lee. 1999. 3rd Edition. Cambridge University Press, Cambridge. 614 pp. Cloth U.S.\$202.60, paper U.S.\$72.85.

Algae

By L. E. Graham and L. W. Wilcox. 2000. Prentice Hall, Upper Saddle River, New Jersey. 640 pp. U.S.\$100.95.

It is a rare event when one can welcome the return of an old friend dressed up in new clothes (Lee) along with a brand new kid on the block (Graham and Wilcox). Lee's text has arguably been the best algal textbook for the last 20 years. The new edition updates a strong second edition (from 1989) and improves the general presentation. Graham and Wilcox (henceforth G&W) have used a new approach, and produced a stunning book that will replace Lee for many people as the textbook of choice. Both of these books offer excellent systematic surveys, great introductions to comparative ultrastructure and the basics of algal physiology, ecology, and cell biology. G&W offer a more comprehensive ecological perspective and have emphasized molecular analyses in putting algae into a phylogenetic context.

The 61-page introductory chapter in Lee describing the basic characteristics of algae may be the single best summary available for algae in that it encapsulates algal diversity in the contexts of morphology, ultrastructure, biochemistry, and ecology. Thus, if you are teaching plant diversity or aquatic ecology, here is the essential information on these organisms. Lee, at 614 pages, is not as comprehensive as G&W with 699 pages (with 50% greater print area per page). This might make Lee more attractive in algal survey courses where one doesn't want students confronted with quite so much information. One of the features of Lee that I have liked from the beginning is the photographs of prominent phycologists. This helps convince students that science is done by people, and that the material in textbooks is not divine revelation!

G&W is simply the best algal textbook to date. The strongest feature is that in addition to the 15 chapter systematic survey of algal groups that is

standard in algal texts, there are eight chapters that are conceptually based and integrate across all algal classes. This includes chapters on biogeochemistry, technological applications, biotic associations, molecular methods and phylogeny reconstruction, endosymbiosis, as well as chapters on phytoplankton, macroalgal, and periphyton ecology. The chapter on phytoplankton ecology contributed by J. M. Graham is one of the highlights of the book. In addition to the word-based descriptions of ecological and biophysical processes, Graham provides quantitative accounts of these phenomena, as well as sufficient background to make it possible to teach this material to undergraduates. This material may not be for everyone, but it helps justify why we make biology students take calculus! One general complaint about this book it is that there are five chapters dedicated to the green algae; i.e., one for each of the classes. Thus the pagination dedicated to brown, red and green algae is 32:54:146. Since the background of the authors is with freshwater algae, this bias does not surprise me. The chapter on biotic associations is weak on marine algal symbioses, and fungi are mentioned only in the context of lichens and microalgae.

The classification in G&W is much more current. Thus the seven orders that Lee recognizes give a very different perspective on phaeophytes than the 14 of G&W. Similarly, the larger number of red algal orders (10 versus 18) gives a more current aspect to G&W. The additional orders of G&W are not a case of splitting, but a recognition that modern morphological and molecular systematics have helped define these monophyletic groups. This difference in conceptual underpinnings is epitomized by the fact there are only two phylogenetic trees in Lee, compared to the numerous cladograms in G&W. These two books are extensively referenced, although G&W has many more bibliographic entries. In addition, G&W appears to be more current with over 40% of the references post 1990. This contrasts with Lee where only 20% of the references are post 1990.

Both books are well illustrated with lots of functional to high quality line drawings, and good to excellent black and white photographs. The line draw-

ings in G&W are much crisper and are drawn in a consistent style. In terms of production values the designers at Prentice Hall have put a lot more thought into G&W than Cambridge did for Lee. Even with similar content, students and teachers will find G&W esthetically more attractive. Both books could have been improved with even a few plates of colour photographs, or simply using a different colour ink to highlight some of the figures and tables. In both books the text is clearly written and is free of typos. Price provides an important distinction: the hard cover version of Lee is out of sight, whereas the hard cover of

G&W is consistent with many university texts. On the one hand, the paper bound version of Lee is a relative bargain, and might decide the choice of text by itself. On the other hand, if you were to have one algal textbook or reference book on your shelf, G&W is the one I would recommend.

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ENVIRONMENT

Something New Under the Sun: An Environmental History of the Twentieth-Century World.

J. R. McNeill. 2000. W. W. Norton, New York. N.Y. Cloth. 421 pp., illus.

Ecclesiastes is out of date; there *is* something new under the sun. The 20th century has been "a gigantic uncontrolled experiment. ... the world economy grew 14-fold. Humankind has begun to play dice with the planet without knowing the rules of the game." We have accepted the century's short-lived abundance of cheap energy and cheap fresh water which have led to rapid and unsustainable growth of human population and of the economy.

When historians discuss the environment, they often do so with little understanding of it. Environmentalists in turn rarely have much knowledge of history. McNeill approaches his topic from the viewpoint of a historian, allowing his abounding and well-documented treasury of facts and figures in most cases to speak for themselves, without extreme alarmism. The thoroughness of two solid years of research into the environmental history of our planet is evident from his 42-page bibliography. He claims to take an anthropocentric view, yet he refers to *Homo sapiens* as a "rogue animal."

McNeill emphasizes the complexities of the interrelationships between soil, atmosphere, water, forests, and humans, and the many unforeseen and unintended effects of human interventions. He explains the sources, amounts, circumstances, and locations of industrial pollutants and of ecologic catastrophes around the world. Coal smoke, sulphur dioxide (the main constituent of acid rain), carbon dioxide (the main greenhouse gas), methane, copper, freon, and other chlorofluorocarbons, you name it, all are documented here. Of 1.8 billion city dwellers, world-wide, one billion breathe unhealthy levels of something harmful.

Follies continue apace. In the United States, Ogallala Aquifer water continues to be pumped above ground by 150 000 pumps at ten times the rate of recharge, half of its water already extracted by 1993.

In Saudi Arabia, it takes a thousand tons of water to grow a ton of wheat. In Libya, water costs four times the value of the crops produced. Engineers have designed expensive monuments, some of them examples of short-sightedness and stupidity. Massive dams have destroyed forests and fisheries, and raised the rates of malaria and schistosomiasis. The Colorado River now delivers only useless brine to its mouth in Mexico. Although Norman Borlaug won the Nobel Peace Prize in 1970 for fathering the Green Revolution, his plant breeding has led inevitably to monoculture crops, reduced biodiversity, use of incremental amounts of fertilizer and pesticides, and the chemicalization and mechanization of agriculture. These in turn have led to salinization of soils, rural instability, poverty, recurrent famines, and massive movements of people into ever-larger cities that are unable to cope. The most valuable fisheries — pilchard, herring, sardine, cod, and anchoveta — have experienced massive collapse. During the century, fin whale populations dropped from 750 000 to 20 000 and blue whales from 200 000 to 500.

One-time resources are being consumed at an unconscionable rate. In 1700 there were five cities with over half a million population, each with a large "ecological footprint" of food, water, and energy input and of waste disposal output; now there are over 1800 cities of this size. Now automobiles use up 5 to 10 percent of the surface area in Europe, the United States, and Japan. In Germany, for every ton of automobile produced, 29 tons of waste result.

While economists ignored nature almost completely, ecologists in general had no political or economic, and hence no ecologic, impact. Rachel Carson in 1963 was the first to get her message across; the first Earth Day in 1970 marked the beginning of attention to ecology. Nevertheless, an international sampling in 1997 revealed that citizens of only five countries, New Zealand, Canada, Switzerland, Austria, and the Netherlands, were willing to give environmental pro-

tection priority over economic growth. The effects of genetic engineering and of computers on the environment remain to be experienced. The effects of global warming, should this process continue, cannot be predicted with any certainty. A further loss of biodiversity seems inevitable.

There have been a very few successes: elimination of lead from gasoline; the cleanup of air and water in Pittsburgh and London; the development of model public transportation and waste recycling in the new city of Curitiba in Brazil.

This book has added to my knowledge and corrected some of my prejudices. In his epilogue, McNeill tells us, "It is impossible to know whether

mankind has entered a genuine ecological crisis. ... By the time we do know, it will be far too late to do much about it." He hopes for new and cleaner energy regimes and for formal education of girls in poor countries, since "female education is the strongest determinant of fertility." History and ecology "need to integrate with one another." Yes. Read this book and you will better understand the history of the world's environment.

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You Are the Earth, From Dinosaur Breath to Pizza from Dirt

By David Suzuki and Kathy Vanderlinden. 1999.
Greystone Books, Douglas & McIntyre, Vancouver. 128 pp., illus. \$24.95.

I like books for young people. They're quick to read. They present clear ideas. They convey just the right amount of information to grasp basic concepts. And they make you want to learn more.

You Are the Earth is no exception. It's a dynamic book, featuring lots of great photographs, illustrations, annotated diagrams, cartoons, activities, glossary and quiz, complementing clear text that makes every possible connection — some I would never have thought of — between *Homo sapiens* and the natural world.

The chapter on air, for example, talks about argon gas. It tells us that the 30 zillion or so argon atoms we exhale with every breath travel through our neighbourhood within minutes, and that within a year they spread around the planet, with about 15 of them returning to our own noses. We also learn that argon atoms never die or change, meaning, as the book points out, that "thousands of years ago, an Egyptian slave building the pyramids breathed some of the same argon atoms that later Joan of Arc, Napoleon, and his horse breathed. And some of those were argon atoms exhaled by dinosaurs that lived 70 million years ago." It's a mind-boggling and playful notion.

Yet the book isn't all fun and games. It also points out the negative impacts humans have on the envi-

ronment. The chapter on energy tells us that plants and animals in the wild use and pass on energy in a continuous cycle, but that humans use energy in a linear manner that leads to waste. The chapter on soil addresses topsoil loss, factory farming, and the use of chemical pesticides and fertilizers. The chapter titled "Depending on Our Relatives" illustrates biodiversity (including the bacteria we host on our own bodies) and emphasizes how human activities are killing off species up to 10 000 times faster than ever before in the history of the planet.

But the book isn't all doom and gloom either. The last chapter provides encouragement. It tells stories of young people who are making a positive contribution to the environment. It gives a list of things kids can do to help the natural world.

And it provides hope: "Our survival depends on remembering who we are. We are the Earth — part of the air, water, soil, and energy of the world; beings with love in our hearts, life in our souls, and a kingdom of kin at our doorstep. It is up to us to protect those things so that they will be around for many generations to come."

If, as a result of reading the book, readers end up believing these things and taking action, it will have fulfilled its purpose.

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The Alvars of Ontario: Significant Alvar Natural Areas in the Ontario Great Lakes Region

By V.R. Brownell and J.L. Riley. 2000. Federation of Ontario Naturalists, Don Mills, Ontario. 269 pp., illus.

Alvars are areas with low tree cover on shallow soils over limestone bedrock. These highly diverse habitats have recently received much attention from the conservation and scientific communities. The purpose of this volume is to assess the conservation value of 92 of the natural areas containing alvars in southern Ontario. The first section provides a general review of the methods the authors used to evaluate sites and details of many aspects of alvar natural history. The second half of the book is devoted to the site-by-site evaluation summaries. While there is much overlap with the final report of the International Alvar Conservation Initiative (Reschke et al. 1999), this report differs in its specificity to Ontario, its coverage of a greater range of natural history information, and the inclusion of more Ontario sites. Being an FON publication, it should also prove easier for the public to get hold of this document.

Generally, the descriptive natural history is excellent and detailed throughout, providing sufficient context for their evaluation of sites. A section on the classification of alvar habitats quickly became overly complicated, however, with the presentation of three separate classification systems. For example, shoreline alvars were discussed as such in the text but classified out of the alvar group into "limestone shorelines" in the displayed table. It became obvious that a definitive classification of alvar habitats is not yet available.

A detailed discussion of the evaluation criteria (representation, diversity, site condition, special features, and ecological function) follows with more reference to natural history details and provides the framework for the site summaries. Having analyzed data from a variety of sources, the authors conclude that 9 of 13 physiographic regions containing alvars do not have adequate protection for significant alvar sites. The analysis thus provides a solid basis for prioritizing conservation actions on Ontario alvars.

Parts of the conclusion section were puzzling,

especially the strong prescriptive statements about fire as a management tool for alvars. The authors claim that "[t]he burning of alvar habitats regardless of presence or absence of past fire, is an appropriate consideration because the vast majority of alvars have burned" page 66. This is out of place in a report that is not primarily about management techniques, especially since the topic of fire receives only one page of text before the conclusions. This idea seems to come from two sources: a single descriptive study on one site (Catling and Brownell 1998) which shows high species richness several decades after a burn, and the evidence of past fires on a number of alvars. Fire evidence in alvar habitats does not imply that alvar community structure is maintained by fire. There is probably evidence that most of Ontario has burned at one time or another, does this mean that all present-day habitats are maintained by fire or should be managed using fire? This reader wanted either a much more tentative statement about fire as a recommended management tool or much more detailed evidence for both the relationship between fire and the maintenance of alvar communities and the threats to which burning would putatively respond. Much research needs to be done on the threats to alvars and the potential management actions necessary to counter them before burning should be universally considered for Ontario alvars. Despite problems in the classification and management sections, the site summaries and natural history details in this book will provide a useful reference for future research, conservation, and management initiatives on alvars in Ontario.

References

- Catling, P. M. and V. R. Brownell. 1998. Importance of fire in alvar ecosystems—evidence from the Burnt Lands, eastern Ontario. *Canadian Field-Naturalist* 112: 661–667
- Reschke, C. et al. 1999. *Conserving Great Lakes Alvars*. The Nature Conservancy, Great Lakes Program, Chicago. 230 pages.

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MISCELLANEOUS

The Essential Aldo Leopold: Quotations and Commentaries

Edited by Curt Meine and Richard L. Knight. 1999. University of Wisconsin Press, Madison. 362 pp., illus. U.S.\$27.95.

Just as Henry David Thoreau is identified with *Walden*, so too is Aldo Leopold with *A Sand Country Almanac*. But Leopold's conservation classic was published a year after his death, the work of a scientist and scholar at the pinnacle of his career. He had spent the better part of his life observing, learning, and thinking about many of the ideas that he presented so eloquently, so forcefully, in the essays in the *Almanac*. And although millions of readers around the world are familiar with Leopold's *Almanac* and the concept of a land ethic, his earlier writing on a wide range of related subjects is largely unknown.

The Essential Aldo Leopold seeks to bring together in a single volume some of the acclaimed conservationist's best work over a thirty-year period — from his days in the U.S. Forest Service to his tenure at the University of Wisconsin. Most are brief extracts from his many articles, essays, and reviews; there are only a few unpublished sources. The quotations have been organized into twenty-one chapters,

grouped around three major themes: conservation science and practice; conservation policy; and conservation and culture. Each chapter is introduced by a specialist, who explains the nature and significance of Leopold's work to that particular field or topic — be it game management or advocacy.

The Essential Aldo Leopold confirms Leopold's position as America's pioneering wildlife ecologist, and a gifted writer. In reading the quotes and commentaries, one is immediately struck by Leopold's ability to express "big" ideas or concepts with clarity and precision. In fact, those looking for that perfect quote for a lecture will find many here. But anyone trying to understand and appreciate how Leopold's thinking evolved will have to look elsewhere. If anything, the collection might encourage readers to go back to the *Almanac* and the simple joys of Wisconsin's sand counties.

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NEW TITLES

Zoology

***Amphibians and reptiles of Pennsylvania and the northeast.** 2001. By A. C. Hulse, J. C. McCoy, and E. Censky. Cornell University Press, Ithaca. 432 pp., illus. U.S. \$39.95.

The animal kingdom: a guide to vertebrate classification and diversity. 2000. By K. Whyman. Raintree Steck-Vaughn, Austin, Texas. 48 pp., illus. U.S. \$25.69.

Animal minds: beyond cognition to consciousness. 2001. By D. R. Griffin. University of Chicago Press, Chicago. xvi + 356 pp. U.S. \$27.50.

Antelopes, deer, and relatives: fossil records, behavioral ecology, and conservation. 2000. Edited by E. S. Vrba and G. B. Shaller, Yale, New Haven. 340 pp., illus. U.S. \$65.

The astonishing elephant. 2000. By S. Alexander. Random House, New York. 300 pp., illus. U.S. \$25.95.

†**Avian research at the Savannah River site: a model for integrating basic research and long-term management.** 2000. Edited by J. B. Dunning, Jr. and J. C. Kilgo. Studies in Avian Biology No. 21. Cooper Ornithological Society, Camarillo, California. 170 pp., illus. U.S. \$20.

Biology of the plant bugs (Hemiptera: Miridae): pests, predators, opportunists. 2001. By A. G. Wheeler, Jr. Cornell University Press, Ithaca. 456 pp., illus. U.S. \$90.

***Birds, mammals, and reptiles of the Galapagos Islands.** 2000. By A. Swash and R. Still. Yale University Press, New Haven. 168 pp., illus. U.S. \$24.95.

***Birds of British Columbia, Volume 4: wood warblers through old world sparrows.** 2001. By R. W. Cambell, N. K. Dawe, I. McTaggart-Cowan, J. M. Cooper, G. W. Kaiser, A. C. Stewart, and M. C. E. McNall. UBC Press, Vancouver. 744 pp., illus. \$125.

***The birds of Ecuador: Volume 1, status, distribution, and taxonomy; and Volume 2, field guide.** 2001. By R. S. Ridgely and P. J. Greenfield. Cornell University Press, Ithaca. 768 pp., illus. and 816 pp., illus. 2 volume set U.S. \$110.

Birds of the Seychelles. 2001. By A. Skerrett and I. Bullock. Princeton University Press, Princeton. 320 pp., illus. U.S. \$39.50.

†**Butterflies of British Columbia.** 2001. By C. S. Guppy and J. H. Sheppard. UBC Press, Vancouver. 414 pp., illus. \$95.

Cetacean societies: field studies of dolphins and whales. 2000. Edited by J. Mann, et al. University Chicago Press, Chicago. xiv + 433 pp., illus. Cloth U.S. \$80; paper U.S. \$35.

Crows and jays. 2001. By S. Madge and H. Burn, Princeton University Press, Princeton. 216 pp., illus. U.S. \$24.95.

- ***The destruction of the bison.** 2000. By A. C. Isenberg. xii + 206 pp., illus. U.S. \$24.95.
- ***Ecology and management of large mammals of North America.** 2000. Edited by S. Demarais and P. Krausman. Prentice Hall, New York.
- †**The ecotraveller's wildlife guide: Alaska.** 2001. By D. Paulson and L. Belestsky. Academic Press, San Diego. xiv + 436 pp., illus. U.S. \$29.95.
- †**Enjoying moths.** 2001. By R. Leverton. Poyser Natural History, London, England. xi + 276 pp., illus.
- †**Evolution, ecology, conservation, and management of Hawaiian birds: a vanishing avifauna.** 2001. Edited by J. M. Scott, S. Conant, and C. vanRiper, III. Cooper Ornithological Society, Camarillo, California. 428 pp., illus. Cloth U.S. \$48.50; paper U.S. \$29.
- †**Estimates of shorebird populations in North America.** 2001. By R. I. G. Morrison, R. E. Gill, Jr., B. A. Harrington, S. Skagen, G. W. Page, C. L. Gratto-Trevor, and S. M. Haig. Canadian Wildlife Service, Ottawa. 64 pp.
- A field guide to the amphibians and reptiles of the Maya world: the lowlands of Mexico, northern Guatemala, and Belize.** 2000. By J. C. Lee. Cornell, Ithaca. xi+402 pp., illus. Cloth U.S. \$ 59.95; paper U.S. \$35.
- Fish watching with Eugenie Clark.** 2000. By M. E. Ross. Lerner, Minneapolis. 48 pp., illus. U.S. \$19.93.
- ***Flying foxes: fruit and blossom bats of Australia.** 2000. By L. Hall and G. Richards. Krieger, Melbourne, Florida. viii + 135 pp., illus. Cloth U.S. 29.50; paper U.S. \$21.50.
- ***Four wings and a prayer: caught in the mystery of the monarch butterfly.** 2001. By S. Halpern. Knopf Canada, Mississauga. 212 pp. \$29.95.
- ***Handbook of birds of the world, volume 6: mousebirds to hornbills.** 2001. Edited by J. del Hoyo, A. Elliot, and J. Sargatal. Lynx Edicions, Barcelona. 589 pp., illus. U.S. \$185.
- †**In search of the golden frog.** 2000. By M. Crump. University of Chicago Press, Chicago. xiv + 299 pp., illus. \$27.
- †**An introduction to the invertebrates.** 2001. By J. Moore. Cambridge University Press, New York. xv + 355 pp., illus. Cloth U.S. \$64.95; paper U.S. \$22.95.
- Kangaroos in outback Australia: Comparative ecology and behavior of three coexisting species.** 2000. By D. R. McCullough and Y. McCullough. Columbia, New York. xvii + 308 pp., illus. Cloth U.S. \$50; paper U.S. \$30.
- Katydid and bush-crickets: reproductive behavior and evolution of the Tettigoniidae.** 2001. By D. T. Gwynne. Cornell University Press, Ithaca. 400 pp., illus. U.S. \$39.95.
- Keepers of the wolves: the early years of wolf recovery in Wisconsin.** 2001. By R. P. Thiel. University Wisconsin Press, Madison. 256 pp., illus. Cloth U.S. \$50; paper U.S. \$50; paper U.S. \$19.95.
- †**Life underground: the biology of subterranean rodents.** 2000. Edited by E. A. Lacey, J. L. Patton, and G. N. Cameron. University Chicago Press, Chicago. xii + 450 pp., illus. Cloth U.S. \$65; paper U.S. \$24.
- Medieval birds in the Sherborne missal.** 2001. By J. Backhouse. University of Toronto Press, Toronto. c64 pp., illus. \$19.95.
- †**A natural history of sex: the ecology and evolution of mating behaviour.** 2001. By A. Forsyth. Firefly, Willowdale, Ontario. 192 pp., illus. \$14.95.
- †**The New York City Audubon Society guide to finding birds in the metropolitan area.** 2001. By M. T. Fowle and P. Kerlinger. Cornell University Press, Ithaca. xix + 230 pp., illus. U.S. \$ 17.95
- The philosophy and practice of wildlife management.** 2001. By F. F. Gilbert and D. G. Dodds. 3rd edition. Krieger Publishing, Melbourne, Florida. 370 pp., U.S. \$34.50.
- ***Pigeons and doves: a guide to the pigeons and doves of the world.** 2001. By D. Gibbs and E. Barnes. Yale University Press, New Haven, 615 pp., illus. U.S. \$60.
- ***Prairie birds: fragile splendor in the Great Plains.** 2001. By P. A. Johnsgard. University Press of Kansas, Lawrence. xvii + 331 pp., illus. U.S. \$29.95.
- Salmon country: a history of the Pacific salmon.** 2000. By R. H. Bush. Firefly, Willowdale, Ontario. 176 pp., illus. U.S. \$ 17.95.
- †**Sea stars of British Columbia, southeast Alaska, and Puget Sound.** 2000. By P. Lambert. Revised edition. UBC Press, Vancouver. 186 pp., illus. \$25.95.
- ***The Sibley guide to birds.** 2000. By D. A. Sibley. National Audubon Society. Knopf (Random House), New York. 544 pp., illus.
- The snakes of Trinidad and Tobago.** 2001. By H. C. A. Boos. Texas A & M University Press, College Station. 328 pp., illus. U.S. \$47.95.
- ***Snipes of the western palearctic.** 2000. By R. Rouxel. Eveil Nature, Saint Yrieux sur Charente, France. 304 pp., illus.
- ***Sylvia warblers.** 2001. By H. Shirihi, G. Gargallo, and A. J. Helbig. Princeton University Press, Princeton. 576 pp., illus. U.S. \$75.
- Thrushes.** 2001. By P. Clement. Princeton University Press, Princeton. 424 pp., illus. U.S. \$ 49.50.
- †**Towards conservation of the diversity of Canada Geese (Branta canadensis).** 2000. Edited by K. M. Dickson. Occasional Paper No. 103. Canadian Wildlife Service, Ottawa. 165 pp., illus.
- Wildlife study design.** 2001. By M. L. Morrison. W. M. Block, M. D. Strickland, and W. L. Kendall. Springer-Verlag, New York. 255 pp., illus. U.S. \$69.95.

Botany

†**The Cambridge illustrated glossary of botanical terms.** 2001. By M. Hickey and C. King. Cambridge University Press, New York. xii + 208 pp., illus. Cloth U.S. \$ 85; paper U.S. \$ 29.95.

***Flora of Florida, Volume 1: pteridophytes and gymnosperms.** 2000. By R. P. Wunderlin and B. F. Hansen. University Press of Florida, Gainesville. xii + 365 pp., illus. U.S. \$49.95.

***Flora of New Brunswick.** 2000. By H. R. Hinds. 2nd edition. Department of Biology, University of New Brunswick, Fredericton. 695 pp., illus. \$50.

The interactive identification of native and naturalized new world Salix using intkey. 2001. By G. Argus. Available from author, 310 Haskins Road, Merrickville R 3, Ontario K0G 1N0. 104 pp., illus. + diskette. \$20.

†**Lichens of Antarctica and South Georgia: a guide to their identification and ecology.** 2001. By D. O. Ovstedal and R. I. L. Smith. Cambridge University Press. New York. xii + 411 pp., illus. U.S. \$ 100.

***North woods wildflowers.** 2001. By D. Ladd. Globe Pequot Press (Canadian distributor or General Publishing, North York). 280 pp., illus. \$39.95.

Painting flowers in watercolour: a naturalistic approach. 2001. By C. G. Guest. Timber Press, Portland, Oregon. 160 pp., illus. U.S. \$ 29.95.

†**Pondweeds, bur-reeds, and their relatives of British Columbia.** 2000. By T. C. Brayshaw. 2nd edition. Royal British Columbia Museum, Victoria. 250 pp., illus. \$24.95.

Weeding through the wilderness: common and scientific names of weeds in Canada. 2000. By Agriculture Canada. Canadian Government Publishing, Ottawa. 132 pp., illus. \$22.

Environment

***AAAS atlas of population and environment.** 2000. By P. Harrison and F. Pearce. University of California Press, Berkeley. Xi + 204 pp., illus. Cloth U.S. \$65; paper U.S. \$29.95.

***The alvars of Ontario: significant alvar natural areas in Ontario Great Lakes Region.** 2000. By V. R. Brownell and J. L. Riley. Federation Ontario Naturalists, Toronto. x + 269 pp., illus.

†**Cognitive ecology of pollination: animal behavior and floral evolution.** 2001. Edited by L. Chittka and J. D. Thomson. Cambridge University Press, New York. xiii + 344 pp., illus. U.S. \$95.

***Ecosystem dynamics of the boreal forest.** 2001. Edited by C. J. Krebs, S. Boutin, and R. Boonstra. Oxford University Press, New York. 512 pp., illus. U.S. \$152.

Encyclopedia of environmental science. 2000. Edited by

J. Morgillo and L. Zierdt-Warshaw. Oryx Press, Phoenix. v + 450 pp., illus. U.S. \$112.25.

***Environmentalism unbound: exploring new pathways for change.** 2001. By R. Gottlieb. MIT Press, Cambridge, Massachusetts. xvii + 396 pp., U.S. \$29.95.

***Finding order in nature: the naturalist tradition from Linnaeus to E. O. Wilson.** 2000. By P. L. Farber. Johns Hopkins University Press, Baltimore. x + 136 pp., illus. Cloth U.S. \$39.95; paper U.S. \$15.95.

†**Genetics, demography, and viability of fragmented populations.** 2000. Edited by A. G. Young and G. M. Clarke. Cambridge University Press, New York. xviii + 438 pp., illus. Cloth U.S. \$110, paper U.S. \$39.95.

Inland flood hazards: human, riparian, and aquatic communities. 2000. By E. E. Whohl. Cambridge, New York. xiv + 498 pp., illus. U.S. \$110.

†**Journeys through paradise: pioneering naturalists in the southeast.** 2001. By G. Fishman. University of Florida Press, Gainesville (Canadian distributor Scholarly Book Services, Toronto). 297 pp. \$41.25.

The Laguna Madre of Texas and Tamaulipas. 2001. Edited by J. W. Tunnell, Jr. and F. W. Judd. Texas A & M University Press, College Station. 384 pp., illus. U.S. \$ 60.

†**Learning to manage global environmental risks: Volume 1, a comparative history of social responses to climate change, ozone depletion, and acid rain; Volume 2, a functional analysis of social responses to climate change, ozone depletion, and acid rain.** 2001. By the Social Learning Group. MIT Press, Cambridge, Massachusetts. 376 pp., illus. Cloth U.S. \$75; paper U.S. \$ 30 and 226 pp., illus. Cloth U.S. \$60; paper U.S. \$ 24.

Naturalist's Big Bend: an introduction to the trees and shrubs, wildflowers, cacti, mammals, birds, reptiles and amphibians, fish, and insects. 2001. By R. H. Waver and C. M. Fleming. Revised edition. Texas A & M University Press, College Station. 232 pp., illus. Cloth U.S. \$29.95; paper U.S. \$15.95.

***Natural selections: national parks in Atlantic Canada, 1935–1970.** 2001. By A. MacEachern. McGill-Queen's University Press, Montreal. 328 pp., illus. \$49.95.

***Northern wild: best contemporary Canadian nature writing.** 2001. Edited by D. R. Boyd. Greystone (Douglas and McIntyre, Vancouver). ix + 278 pp., \$22.95.

Picturing tropical nature. 2001. By N. L. Stepan. Cornell University Press, Ithaca. 256 pp., illus. U.S. \$35.

†**A primer of ecology.** 2001. By N. J. Gotelli. 3rd edition. Sinauer, Sunderland, Massachusetts. xxi + 265 pp., illus. U.S. \$ 31.95.

†**Snow ecology: an interdisciplinary examination of snow-covered ecosystems.** 2001. Edited by H. G. Jones, J. W. Pomeroy, D. A. Walker, and R. W. Hoham. Cambridge University Press, New York. xx + 378 pp., illus. U.S. \$80.

†**Thieves, deceivers, and killers: tales of chemistry in nature.** 2001. By W. Agosta. Princeton University Press, Princeton. 241 pp., illus. U.S. \$26.95.

Miscellaneous

†**Cabins: a guide to building your own nature retreat.** 2001. By D. and J. Stilles. Firefly Books, Willowdale, Ontario. 232 pp., illus. Cloth \$29.95; paper \$19.95.

†**The complete guide to walking in Canada.** 2001. By E. Katz. Firefly Books, Willowdale, Ontario. 360 pp., illus. \$16.95.

†**Cradle of life: The discovery of earth's earliest fossils.** 2001. By J. W. Schopf. Princeton University Press, Princeton. xv + 367 pp., illus. U.S. \$17.95.

†**Memorabilia of activities of William W. Judd while with the Canadian Meteorological Service during World War II, 1942 to 1945.** 2001. By W. W. Judd. Phelps Publishing, London, Ontario. 98 pp., illus. \$10.

†**Memorabilia of Robert Elliott (1858–1902) poet and naturalist of Plover Mills, Middlesex County, Ontario.** 2001. By W. W. Judd, 50 Hunt Club Drive, London, Ontario N6H 3Y3. 75 pp., illus. \$10.

†**Minutes of meetings, 1956 to 1960, of the McIlwraith Ornithological Club London, Ontario, Canada.** 2001. By W. W. Judd. Phelps Publishing (order from author, Greenpeace, 50 Hunt Club Drive, London, Ontario N6H 3Y3) 81 pp. \$10.

†**Permafrost: a guide to frozen ground in transition.** 2001. By N Davis. University of Alaska Press, Fairbanks. xvi + 351 pp., illus. U.S. \$35.95.

***Sir William Jardine: a life in natural history.** 2000. By C. E. Jackson and P. Davis. Leicester University Press, London. 256pp., illus. £55.

***Their father's work: casting nets with World's fishermen.** 2000. By W. McCloskey. McGraw-Hill, Scarborough. 307. pp., \$20.95.

Books for Young Naturalists

About insects: a guide for children. 2000. By C. Sill. Peachtree, Atlanta. 48 pp., illus. U.S. \$14.95.

The age of dinosaurs. 2000. By S. Parker. Grolier, Danbury, Connecticut. 58 pp., illus. Each of 12 Volume set. U.S. \$249 for set.

Animal lives: the frog and Animal lives: the rabbit. 2000. By S. Tagholm. Kingfisher, New York. Each 32 pp., illus. U.S. \$9.95.

Animals among us: living with suburban wildlife. 2000. By F. Hodgkins. x + 117 pp., illus. U.S. \$19.50.

Animals in cold places. 2000. By M. Butterfield. Raintree Steck-Vaughn, Austin, Texas. 32 pp., illus. U.S. \$22.83.

Beetles; Flies. 2000. By E. Pascoe. Blackbirch, Woodbridge, Connecticut. Each 48 pp., illus. U.S. \$18.95.

Destination Australia. 2000. By J. Gupper. National Geographic Society, Washington. 32 pp., illus. U.S. \$16.95.

Eagles. 2000. By D. Hodge. Kids Can Press, Niagara Falls, New York. 32 pp., illus. Cloth U.S. \$10.95; paper U.S. \$5.95.

HEco-fun: great projects, experiments, and games for a greener earth. 2001. By D. Suzuki and K. Vanderlinden. Greystone Books, Douglas and McIntyre, Vancouver. 128 pp., illus. \$14.95.

Exploring the universe: science activities for kids. 2000. By A. D. Fredericks. Fulcrum, Golden, Colorado. 128 pp., illus. U.S. \$16.95.

Feet that suck and feed. 2000. By D. Swanson. Greystone, Vancouver. 30 pp., illus.

A fish caught in time: the search for the coelacanth. 2000. By S. Weinberg. Harper Collins Children's, New York. xx + 220 pp., illus. U.S. \$24.

Great grizzly wilderness: a story of the Pacific rain forest. 2000. By A. Fraggalosch. Soundprints, Norwalk, Connecticut. 35 pp., illus. U.S. \$15.95.

My monarch journal: parent-teacher edition. 2000. By C. Muther. Dawn, Nevada City, California. 52 pp., illus. U.S. \$9.95.

Partners and parents; Plants and planteaters; Poisoners and pretenders; Predators and pray. 2000. By M. Chinery. Secrets of the Rainforest Series. Crabtree, New York. Each 32 pp., illus. Cloth U.S. \$14.97; paper U.S. \$7.16.

Realm of the panther: a story of south Florida forests. 2000. By E. Costello. Soundprints, Norwalk, Connecticut. 35 pp., illus. U.S. \$15.95.

The Rocky Mountains. 2001. By L. Bogard. Ecosystems of the World Series. Benchmark Books, Tarrytown, New York. 64 pp., U.S. \$18.95.

Science experiments. 2000. By A. Hansen. Lowell House, Los Angeles. 112 pp., illus. U.S. \$8.95.

Sockeye's journey home: the story of the Pacific salmon. 2000. By B. G. Winkelman. Soundprints, Norwalk Connecticut. 32 pp., illus. U.S. \$15.95.

Taking root. 2000. by A. Fowler. Children's Press, Danbury, Connecticut. 32 pp., illus. Cloth U.S. \$19; paper U.S. \$4.95.

The winking, blinking sea: all about bioluminescence. 2000. By M Batten. Millbrook Press, Brookfield, Connecticut. 30 pp., illus. U.S. \$20.99.

†Available for review

*Assigned for review

Minutes of the 122nd Annual Business Meeting of the Ottawa Field-Naturalists' Club, 9 January 2001

Place and time: Canadian Museum of Nature, Ottawa, Ontario, 7:30 pm
Chairperson: Eleanor Zurbrigg, President
Attendance: Thirty-one persons attended the meeting

Attendees spent the first half-hour reviewing the minutes of the previous meeting, the Treasurer's report and the Report of Council. The meeting was called to order at 7:56 pm.

1. Minutes of the Previous Meeting

In the heading of the minutes, the date should read "January 11, 2000".

In section 5, "Committee Reports", the motion to approve the report of the Education & Publicity Committee, second sentence, the final words in parentheses should read "slide shows".

Moved by Dave Moore and seconded by Colin Gaskell, that the minutes be accepted as amended.

(Motion Carried)

2. Business Arising from the Minutes

In response to a recommendation by Claudia Burns at the previous meeting, that the Club make an effort to be more accessible to new members, Eleanor Zurbrigg described several initiatives that had been taken during the year.

3. Communications Relating to the Annual Business Meeting

There were no communications relating to the Annual Business Meeting.

4. Treasurer's Report

Frank Pope reviewed the financial report for the year ending September 30, 2000, noting a favourable report from the Auditor and the fact that the Club's net assets had increased by \$8154. In response to a question from Fenja Brodo, he explained that "other revenue" in the note for the Fletcher Wildlife Garden included funds raised from activities such as the Taverner Cup Competition.

Moved by Frank Pope and seconded by Colin Gaskell that the Financial Report be accepted.

(Motion Carried)

5. Committee Reports

Eleanor Zurbrigg introduced each of the Committee reports and a representative of the appropriate Committee and asked for questions and comments.

Dave Moore commented that future reports of the Macoun Club should include more information about

the activities of the Club. Fenja Brodo asked whether participation in the Macoun Club had increased. There was no representative to give a definitive answer, but Eleanor Zurbrigg said she thought that it had.

Ron Bedford gave a number of numerical changes to the report of the Publications Committee.

Moved by Ken Allison, seconded by Dave Moore, that the reports as amended be accepted.

(Motion Carried)

6. Nomination of the Auditor

Moved by Frank Pope, seconded by Bill Cody, that Janet Gehr continue as Auditor for another year.

(Motion Carried)

7. Report of the Nominating Committee

The Committee recommended the following list of candidates for the 2001 Council (new members are indicated by an asterisk)

<i>President</i>	Eleanor Zurbrigg
<i>Vice-President</i>	Roy John
<i>Recording Secretary</i>	Ken Allison
<i>Treasurer</i>	Frank Pope

Other Members:

Ron Bedford	Terry Higgins
Roseanne Bishop*	David Hobden
Fenja Brodo	Bev McBride
Irwin Brodo*	Garry McNulty*
John Cameron*	Dave Moore
Bill Cody	Rita Morbia*
Francis Cook	Bob Roach
Barbara Gaertner	Stan Rosenbaum
Tony Halliday	Dave Smythe

Six members of the 2000 Council decided not to stand for re-election: Sarah Coulber, Ellaine Dickson, John Martens, Philip Martin, Jim Sutton, and Dorothy Whyte. Colin Gaskell thanked these members for their contribution to the Club.

Moved by Colin Gaskell, seconded by Frank Pope, that the list of nominations for the 2001 Council be accepted.

(Motion Carried)

8. New Business

Eleanor Zurbrigg noted that the year 2001 is the "International Year of Volunteers" and welcomed suggestions for increasing the volunteer involvement of members in the administration of the Club.

9. Presentation by the Birds Committee

Bev McBride gave a presentation about the structure and activities of the Birds Committee, noting that it is the largest of the present committees. For the past twenty years the Birds Committee has con-

ducted the Christmas Bird Count, an important activity which was initiated in the Ottawa area around the turn of the century.

10. Adjournment

Moved by David Hobden, seconded by Stan Rosenbaum that the meeting be adjourned at 9:10 pm.

(Motion Carried)

DAVE SMYTHE
Acting Recording Secretary

The Ottawa Field-Naturalists' Club Committee Reports for 2000

Awards Committee

The following awards were presented at the Annual Soiree, held on 14 April 2000:

MEMBER OF THE YEAR AWARD: **Claudia Burns** for her work at the Fletcher Wildlife Garden and in particular with the backyard garden project.

GEORGE MCGEE SERVICE AWARD: **Betty Campbell** for her extensive Club activities including work at the Fletcher Wildlife Garden, Club displays at various venues, work with the Education and Publicity Committee, and organization of the Club's huge collection of slides.

CONSERVATION AWARD FOR MEMBER: **Stan Rosenbaum** for his leadership as chair of the OFNC Conservation Committee, revitalized the committee to the point where it is once again one of the largest and most active of the OFNC committees.

CONSERVATION AWARD FOR NON-MEMBER: **Friends of Petrie Island**, a community-based group, for its remarkable job in the past two years of focusing public and political attention on this special area in the Ottawa River.

HONORARY MEMBER: **Ted Mosquin** for his many years of significant contributions to both the OFNC and to Canadian natural history and its conservation.

The awards nomination form was re-designed for inclusion each year with the fourth issue of Trail & Landscape, rather than with membership renewal notices, in an effort to provide the membership with a more visible solicitation for input into the awards process.

S. DARBYSHIRE

Birds Committee

The Birds Committee participated jointly with the Club des Ornithologues de l'Outaouais to run a successful Christmas Bird Count at the end of 1999. Plans are in place for the 2000 count. We also had a well-attended fall bird count in October 2000. We participated in the Peregrine Falcon Watch at the downtown Ottawa nest site. One youngster survived the fledgling season, and an adult bird appears to be wintering downtown. The Bird Records Subcommittee has reviewed records of rare birds for the area and will publish the findings in an upcoming Trail and Landscape. We added a new ad hoc sub-committee this year, as plans for the 2nd Ontario Breeding Bird Atlas are underway. The chair of the sub-committee is the regional

coordinator for the atlas. Our Seed-a-thon raised around \$800.00 for the Club's bird feeders. Our bird study group held two well-attended training sessions during the year. We also revised the rare bird alert telephone tree and continued to operate the Ottawa Bird Status Line (a recorded telephone message service indicating current bird sightings).

B. MCBRIDE

Computer Management Committee

The Committee provided support services for the Membership database, the accounting system, the computer systems for Trail & Landscape and The Canadian Field-Naturalist, and maintained the OFNC web site. In particular, it upgraded the accounting system to make it Y2K compatible. The Committee operated without a chairperson for most of the year and was unable to undertake any new initiatives.

D. SMYTHE

Conservation Committee

Alfred Bog: The Prescott-Russell Official Plan (protecting against draining of adjacent land for peat extraction) took effect December 31, but is being appealed to OMB. OFNC has status as a participant at hearings. Meeting held between Frank Pope and Minister John Baird regarding need for peat legislation. Letters drafted for FON and OFNC signatures. Bird Studies Canada: Contribution of \$1,000 from the de Kiriline-Laurence Fund to Norfolk Field Naturalists new headquarters. Green Map: the Committee recommended OFNC support, but a later invitation that OFNC become its main sponsor was declined by Council. The Committee co-operated with Green Map to mount a display at the OFNC June 4th Open House. Petrie Island: comments made on City of Cumberland proposed interpretive trail system. Petrie Island is now better known to the public and has many defenders. New reserves: letters sent to OMNR supporting proposals for Burnt Lands Nature Reserve, and White Lake Conservation Reserve. Canadian Environmental Assessment Act (CEAA) 5-year review: Written submission made. Consultants' Management Proposals for Shirley's Bay: comments made on first draft and on full report. Comments were printed in the July-Sept. issue of Trail & Landscape. Leitrim Wetlands: increased concern as a result of Regional Council allocation of \$6M funds for infrastructure in the area of the proposed subdivision. Letters sent to Region and to the Department

of Fisheries and Oceans. Goulbourn Township: letters exchanged with OMNR regarding applications for subdivisions — Upper Poole Creek and Fernbank wetland. The former application was denied, but subject to OMB appeal. Fernbank application is presently denied owing to wetland encroachment, but OMNR advised that wetland draining by private landowners is not prohibited in all cases. A follow-up response was drafted. Species At Risk Act (SARA): Letters of support sent, but Bill C-33 died with election call. Ottawa Transition Team: Three OFNC members attended a meeting with transition staff on Environmental Advisory Committees. Our comments were made verbally and by letter.

S. ROSENBAUM

Education and Publicity Committee

Education on natural history was promoted through provision of volunteer leaders for nature outings and talks, including four outings in Mer Bleue with Beavers, Cubs and Girl Guides, and four outings in Gatineau Park and along the Ottawa River with other organizations.

OFNC displays were presented at the Annual OFNC Soirée, National Wildlife Week at Carlingwood Shopping Centre (18 volunteers), Environment Week at Place du Portage, OFNC Volunteer Day at the Fletcher Wildlife Garden, and for the FON at the Carleton Teachers' Federation PD day. A special display was prepared for the Macoun Field Club and presented at the Greenbank Middle School Environmental Conference. The Committee also provided judges for the Ottawa Regional Science Fair. Three OFNC prizes were awarded. Monthly lectures were advertised through notices to public libraries.

Sales of club merchandise totaled approximately \$500.00. At the sale table at the Monthly Lecture series, the Committee started featuring publications which are on the topic of that evening's presentation, with good results.

B. CAMPBELL

Excursions and Lectures Committee

The Excursions and Lectures Committee arranged 42 outings. There were 16 outings to study birds, six for plants, four for insects, and six to observe amphibians, fish, fungi, geology and astronomy, while another 10 outings were general in nature. The bird outings included two popular annual excursions to Presqu'île and Derby Hill. One further birding event was organized in conjunction with the Fletcher Wildlife Garden. Our program also included nine regular monthly meetings at the Canadian Museum of Nature and the Annual Soirée.

P. MARTIN

Executive Committee

The Executive Committee, with other interested members of Council, met once in April 2000, to reach a decision on the Green Map Project proposal. This proposal invited the OFNC to accept sponsorship and responsibility for the project and its website. It was decided that, while the Club supported "in principle" the project, it was not in a position to become directly involved in management of the project. The Club could be involved as a provider of available natural history data for the project, and would anticipate being a user of Green Map products in the future.

E. ZURBRIGG

Finance Committee

The Committee met four times. In December 1999, the Committee examined the preliminary (pre-audit) Financial Statement for 1998/1999. The draft statement was presented by the Treasurer to the Council's December meeting and approved at the Club's Annual Business Meeting. The Statement showed small surpluses on both the OFNC and CFN accounts.

At two meetings held in the Spring, the Committee prepared a recommendation to Council on the disposition of the Manning bequest. The recommendation was adopted by Council at its June 2000 meeting.

The Committee continued its examination of ways to improve the transparency and usefulness of the accounting system. The Treasurer prepared a numbered break-down of budget revenue and expenditure heads to facilitate accurate recording of expenditures by Committee Chairs and the Treasurer's Assistant.

In August, the Committee prepared a draft budget for 2000/2001. This was presented to Council in September 2000 and, after adjustments, accepted at its October meeting.

The Committee recommends no change in the membership fee structure.

A. HALLIDAY

Fletcher Wildlife Garden Committee

The level of activity at the garden remained steady in 2000 compared to the previous year, with a total of about 2,500 volunteer hours contributed. The Friday morning Backyard Garden crew again gave unstintingly of their time every week to improve the showpiece for the Fletcher garden. Regular clean ups were held using OFNC volunteers. The spring plant sale and exchange raised funds for garden operations.

In addition to several special events, including a workshop on invasive species and a course on wildflower gardening by Philip Fry, the Interpretive Centre was open to the public every Sunday over the summer. A new project was started in partnership with a professor at Carleton University to explore methods to control the very invasive Black Swallowwort. Wildlife gardening publications were produced and disseminated to the public supported mainly by a grant from the Canada Trust Friends of the Environment Program.

The Taverner Cup birding competition was hosted at the FWG on May 27. About \$900 was raised for the garden, with six competitive and 12 recreational teams participating.

The FWG continued to be a central location for OFNC activities, with a Club membership drive hosted at the garden in June. Club Council and committees, including the Birds Committee, meet regularly in the Interpretive Centre.

P. HALL

Macoun Field Club Committee

The Committee met five times to plan the weekly programs for Club members. In addition to the regular schedule of speakers and natural history workshops, committee members led 21 field trips and four camping trips.

B. GAERTNER

Membership Committee

The distribution of memberships for 2000 is shown in

the table (below), with the comparable numbers for 1999 in brackets. These statistics do not include four complimentary memberships awarded to winners of the 2000 Science Fair competition, nor the 22 affiliate organizations which receive copies of the Club's publications.

The Club awarded an Honorary Membership to Ted Mosquin for his contributions to the Club and to Canadian natural history (see T&L volume 34, number 3).

Two prominent and long-time members of the Club passed away this year. Verna Ross McGiffin had been a member of the Club since 1944, and was given Honorary Membership in 1983. Dr. Clarence Frankton had been a member of the Club since 1946, and was given Honorary Membership in 1979.

D. SMYTHE

Publications Committee

The Committee met twice. Three issues of The Canadian Field-Naturalist were published: Volume 114, #1,2,3. These three issues contained: 554 pages; 45 articles; 21 notes; four COSEWIC articles; 40 book reviews; 198 new titles; one commemorative tribute; and 22 pages of News and Comment. There were no changes in the panel of Associate Editors. However, Warren Ballard indicated that he will step down with the completion of volume 114, and a replacement has been approached. Three articles published in Volume 113 qualified for support from the Manning Memorial Fund.

Four issues of Volume 34 of Trail & Landscape containing 164 pages were published.

R. BEDFORD

Distribution of memberships in The Ottawa Field-Naturalists' Club

Type	CANADIAN		FOREIGN		Total
	Local	Other	USA	Other	
Family	350 (360)	23 (23)	2 (2)	1 (2)	376 (387)
Individual	340 (344)	122 (125)	25 (23)	4 (3)	491 (495)
Honorary	15 (14)	8 (8)	0 (0)	0 (0)	23 (22)
Life	22 (17)	21 (21)	5 (5)	1 (1)	49 (44)
Sustaining	8 (8)	1 (0)	0 (0)	0 (0)	9 (9)
Total	735 (743)	175 (178)	32 (30)	6 (6)	948 (957)

Auditor's Report

To The Members of THE OTTAWA FIELD-NATURALISTS' CLUB

I have audited the balance sheet of THE OTTAWA FIELD NATURALISTS' CLUB as at September 30, 2000, the statement of changes in net assets, and the statements of operations. These financial statements are the responsibility of the organization's management. My responsibility is to express an opinion on these statements based on my audit.

Except as explained in the following paragraph, I conducted my audit in accordance with generally accepted auditing standards. Those standards require that I plan and perform an audit to obtain reasonable assurance whether the financial statements are free of material misstatement. An audit includes examining evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation.

In common with many non-profit organizations, the Ottawa Field-Naturalists' Club derives some of its revenue from memberships, donations, and fund raising activities. These revenues are not readily susceptible to complete audit verification, and accordingly, my verification was limited to accounting for the amounts reflected in the records of the organization.

In my opinion, except for the effect of the adjustments, if any, which I might have determined to be necessary had I been able to satisfy myself concerning the completeness of the revenues referred to in the preceding paragraph, these financial statements present fairly, in all material respects, the financial position of the OFNC as at September 30, 2000, and the results of its operations and changes in net assets for the year then ended in accordance with generally accepted accounting principles.

JANET M. GEHR, C.A.
Chartered Accountant

North Gower, Ontario
December 28, 2000

The Ottawa Field-Naturalists' Club Balance Sheet September 30, 2000

	2000	1999
ASSETS		
CURRENT		
Cash	\$ 9,519	\$ 28,378
Investment certificates	106,939	206,435
Marketable securities	185,765	79,568
Accounts receivable	19,689	9,287
Prepaid expenses	1,000	1,000
	<u>322,912</u>	<u>324,668</u>
CAPITAL ASSETS (Note 3)	—	—
Land — Alfred Bog	<u>3,348</u>	<u>3,348</u>
	<u>\$ 326,260</u>	<u>\$ 328,016</u>
LIABILITIES AND FUND BALANCES		
CURRENT		
Accounts payable and accrued liabilities	\$ 2,000	\$ 14,000
Deferred revenue	<u>13,532</u>	<u>13,800</u>
	<u>15,532</u>	<u>27,800</u>
Life memberships	<u>11,249</u>	<u>8,891</u>
NET ASSETS		
Unrestricted	166,721	162,676
Club reserve	100,000	100,000
Manning interest — OFNC	1,203	—
— CFN	4,813	—
Seedathon	1,308	1,193
Anne Hanes memorial	870	870
de Kiriline-Lawrence	22,941	25,211
Macoun Baillie Birdathon	1,039	826
Alfred Bog	<u>584</u>	<u>549</u>
	<u>299,479</u>	<u>291,325</u>
	<u>\$ 326,260</u>	<u>\$ 328,016</u>

The Ottawa Field-Naturalists' Club		
Statement of Operations		
For the Year Ended September 30, 2000		
	2000	1999
REVENUE		
Memberships	\$ 15,355	\$ 14,646
Trail and Landscape.....	224	226
Interest	1,433	1,725
GST rebate.....	915	1,132
Fletcher Wildlife Garden	–	1,245
Other	680	1,573
	<u>18,607</u>	<u>20,547</u>
OPERATING EXPENSES		
Affiliation fees	1,309	1,094
Computer	444	(66)
Membership.....	1,732	1,656
Office assistant	1,000	1,000
Telephone	1,206	1,202
Insurance.....	655	871
Audit	1,000	–
GST.....	1,494	1,710
Operations.....	2,037	925
	<u>10,877</u>	<u>8,392</u>
CLUB ACTIVITY EXPENSES		
Awards.....	215	165
Birds.....	875	400
Education and Publicity	387	217
Excursions and lectures	(98)	(160)
Macoun Field Club	1,151	783
Soiree	429	304
Trail and Landscape.....	8,256	7,788
Fletcher Wildlife Garden	2,132	–
Other	(66)	170
	<u>13,281</u>	<u>9,667</u>
	<u>24,158</u>	<u>18,059</u>
EXCESS REVENUE		
OVER EXPENSES	<u>\$ (5,550)</u>	<u>\$ 2,488</u>

The Ottawa Field-Naturalists' Club		
Statement of Operations —		
The Canadian Field-Naturalist		
For the Year Ended September 30, 2000		
	2000	1999
REVENUE		
Memberships	\$10,253	\$ 9,776
Subscriptions	26,509	30,734
Reprints.....	7,033	12,823
Publication charges.....	39,888	34,498
Interest and exchange	8,519	11,198
GST rebate	4,590	3,839
Other	706	3,595
	<u>97,498</u>	<u>106,463</u>
EXPENSES		
Publishing	58,461	58,707
Reprints.....	6,135	5,423
Circulation	6,070	12,048
Editing	3,258	4,541
Office Assistant	5,000	5,000
Honoraria	6,000	6,000
GST.....	6,045	6,348
Other	2,020	3,609
	<u>92,989</u>	<u>101,676</u>
EXCESS REVENUE OVER		
EXPENSES	<u>\$ 4,509</u>	<u>\$4,787</u>

The Ottawa Field-Naturalists' Club Statement of Changes In Net Assets For the Year Ended September 30, 3000

Net Assets	Beginning Balance	Excess Revenue CFN	Excess Revenue OFN	Donations Contributions	Expenses	2000 Ending Balance
Unrestricted	\$ 162,676	\$ 4,509	\$ (5,550)	\$ 5,086	\$ -	\$ 166,721
Club Reserve	100,000	-	-	-	-	100,000
Manning – OFNC	-	-	-	1,203	-	1,203
Manning – CFN	-	-	-	4,813	-	4,813
Seedathon	1,193	-	-	633	518	1,308
Anne Hanes Memorial	870	-	-	-	-	870
de Kirilin-Lawrence	25,211	-	-	1,404	3,674	25,211
Macoun Baillie Birdathon	826	-	-	213	-	1,039
Alfred Bog	549	-	-	35	-	584
	<u>\$ 291,325</u>	<u>\$ 4,509</u>	<u>\$ (5,550)</u>	<u>\$ 13,387</u>	<u>\$ 4,192</u>	<u>\$ 299,479</u>

The Ottawa Field-Naturalists' Club Summary of Significant Accounting Policies

September 30, 2000

1. Nature of Business

The organization is non-profit and incorporated under the laws of Ontario (1884). The organization promotes the appreciation, preservation, and conservation of Canada's natural heritage. It encourages investigation and publishes the results of the research in all fields of natural history and diffuses information on these fields as widely as possible. It also supports and cooperates with other organizations engaging in preserving, maintaining or restoring environments of high quality for living things.

2. Financial Instruments

The organization's financial instruments consist of cash, accounts receivable, marketable securities, and accounts payable. Unless otherwise noted, it is the management's opinion that the organization is not exposed to significant interest, currency, or credit risks arising from these financial instruments. The fair value of these instruments approximate their carrying values.

3. Capital Assets

Capital assets acquired after 1989 are expenses. Capital assets acquired prior to 1990 were recorded as assets at cost and amortized on a straight-line basis. These assets have been fully amortized.

4. Statement of Changes in Financial Position

A statement of changes in financial position has not been provided as it would not provide additional meaningful information.

5. Foreign Currency

Transactions during the year in U.S. dollars have been converted in the accounts to Canadian dollars at the exchange rate effective at the date of the transaction. All monetary assets in U.S. dollars at year end have been converted to Canadian dollars at the rate effective on Sept. 30, 2000. Gains or losses resulting therefrom are included in revenue or expenses.

News and Comment

***Froglog*: Newsletter of the Declining Amphibian Populations Task Force (45, 46)**

Number 45, June 2001, contains: Contemporary conservation considerations for Nigerian amphibians (G. C. Akani and L. Luiselli) — The DAPTF Captive Breeding Working Group (Andrew Gray) — Limb deformities in the Marine Toad in Peru and Bermuda (Donald W. Linzey) — Amphibian Status in Serbia and Montenegro (FR Yugoslavia) (Milos Kalezic and Georg Dzukic) — *Froglog* Shorts — Publications of Interest.

Number 46, August 2001, contains: Successful treatment of Chytridiomycosis (Donald K. Nichols and Elaine W. Lamirande) — The frog princess and other projects (Mark Pestov and Vladimir Anufriev) — Parasitic copepods responsible for limb abnormalities? (Leong Tzi Ming) — Reduced genetic diversity in Swiss populations of the Italian Agile Frog, *Rana latastei* (Trent Garner and Peter Pearman) — Habitat fragmentation and amphibian species richness in

riparian areas of the Parana River, Argentina (Paola M. Peltzer and Rafael. C. Lajmanovich) — *Froglog* Shorts — Publications of Interest.

Froglog is the bi-monthly newsletter of the Declining Amphibian Populations Task Force of The World Conservation Union (IUCN)/Species Survival Commission (SSC) and is supported by The Open University, The World Congress of Herpetology, The Smithsonian Institution, and Harvard University. The newsletter is Edited by John W. Wilkins on, Department of Biological Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail: daptf@open.ac.uk. Funding for *Froglog* is underwritten by the Detroit Zoological Institute, P. O. Box 39, Michigan 48068-0039, USA. *Froglog* can be accessed at <http://www2.open.ac.uk/biology/froglog/>

***Marine Turtle Newsletter* (93)**

The July 2001 issue, 52 pages, contains: ARTICLES: Preliminary evaluation of helicopter survey as a method of assessing sea turtle nesting distribution in the Ten Thousand Islands of Florida (Ahjond S. Garmestani, H. Franklin Percival, and Kenneth M. Portier) — The National Marine Park of Zakynthos: A refuge for the Loggerhead Turtle in the Mediterranean (Dimitrios Dimopoulos) — NOTES: Record of pelagic East Pacific Green Turtles associated with *Macrocystis* mats near Baja California Sur, Mexico (Wallace J. Nichols, Louise Brooks, Melania Lopez, and Jeffrey A. Seminoff) — Organisational profile: Ghana Wildlife Society (Richard Adjei, Gerard Boakye, and Samuel Adu) — Organisational profile: Save Our Sea Turtles (SOS) Tobago: A research, education and action programme (REAP) (Nicole Leotaud) — Third Leatherback Turtle stranding in Belgium (Jan Haelters, Francis

Kerckhof and Thierry Jauniaux) — BOOK REVIEW — OBITUARIES: Dr. Elvira Carrillo Cardenas (1941-2001) Fred H. Berry — ANNOUNCEMENTS — MEETING REPORTS — NEWS & LEGAL BRIEFS — RECENT PUBLICATIONS.

The Marine Turtle Newsletter is edited by Brendan J. Godley and Annette C. Broderick, Marine Turtle Research Group, School of Biological Sciences, University of Wales, Swansea, SA2 8PP Wales, United Kingdom; e-mail MTN@swan.ac.uk; Fax +44 1792 295447. Subscriptions to the MTN and donations towards the production of MTN and its Spanish edition NTM [Noticiario de Tortugas Marinas] should be sent to Marine Turtle Newsletter c/o Chelonian Research Foundation, 168 Goodrich Street, Lunenburg, Massachusetts 01462 USA; e-mail RhodinCRF@aol.com; fax + 1 978 582 6279. MTN web-site is: <http://www.seaturtle.org/mtn/>

Canadian Species at Risk May 2001

Issued by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), the list is 31 pages containing [1] About COSEWIC, (mandate, membership and definitions); — [2] Summary Tables (COSEWIC species at risk, not at risk, and data deficient; results of May 2001 COSEWIC meeting), [3] COSEWIC Lists (Explanation of symbols, Geographical occurrence and abbreviations; List 1 Species designated in the five "risk" categories, List 2.

Species examined and designated in the NOT AT RISK category; List 3 Species examined and designated in the DATA DEFICIENT category) — [4] Record of Status Re-examinations — [5] List of name changes.

It is available from COSEWIC Secretariat, Chief, Coleen Hyslop, c/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3. See Web site: <http://www.cosewic.gc.ca>

***Recovery*: June 2001**

This issue contains: Recovery Highlights – Profile: Experience and respect central to team's success (David Wylynko) – Special Report: 'Canadian' Burrowing Owls found in Mexico: Culmination of a ten-year search (Geoffrey L. Holroyd and Helen Trefry) – News Bites – Field Notes – Announcements (New Publications, Site seeing, Upcoming events, Awards) – Featured Species: First Nation's involvement is Key (William Andrew: Oregon Spotted Frog *Rana pretiosa* in Frazer River Lowlands of southwestern British Columbia).

Recovery is a free newsletter providing information and views on the recovery of species at risk published by the Canadian Wildlife Service, and edited and designed by West Hawk Associates, Inc. It is available in either english or french [as Sauvegarde] from Canadian Wildlife Service, Environment Canada, Ottawa, Ontario, K1A 0H3 and is accessible at www.cws-scf.ec.gc.ca/es/recovery/archive.html

Amphipacifica: Journal of Aquatic Systematic Biology 3(1) 16 May 2001

CONTENTS: Norma E. Jarrett, 1931–2001: A tribute — The amphipod superfamily Leucothoidea on the Pacific coast of North America: Family Amphilochidae: systematics and distributional ecology (P. M. Hoover and E. L. Bousfield) — The genus *Anisogammarus* (Gammaroidea: Anisogammaridae) on the Pacific coast of North America (E. L. Bousfield) — An updated commentary on phyletic classification of the amphipod Crustacea and its application to the North American fauna (E. L. Bousfield).

Amphipacifica is published by Amphipacifica Research Publications. Dr. E. L. Bousfield, Managing Editor, Ottawa; Dr. D. G. Cook, Technical Editor, Greely, Ontario. Subscriptions (4 numbers per volume) are renewable at \$50 (Can) or \$40 (US) including surface postage. Author charges are \$25 per printed page, subject to change. For further information please contact Dr. E. L. Bousfield, Managing Editor, 1710-1275 Richmond Road, Ottawa, Ontario, Canada K2B 8E3; e-mail: elbousf@magma.ca

Alberta Wildlife Status Reports: (32 to 36)

The Fisheries and Wildlife Management Division of the Alberta Natural Resource Status and Assessment Branch, Alberta Environmental Protection, has released new Wildlife Status Reports. The Series Editor is Isabelle M. G. Michaud, the Senior Editor is David R. C. Prescott, and the illustrations are by Brian Huffman. For a listing earlier numbers in the series, see *The Canadian Field-Naturalist* 112(1): 169 for 1–11; 113(2): 311 for 12–17; 113(4): 686 for 18–21; 114(1): 151 for 22–25; 115(2): 390 for 26–31.

Reports issued March–May 2001 are:

32. Status of the Bay-breasted Warbler (*Dendroica castanea*) in Alberta, by Michael Norton. 21 pages.
33. Status of the Cape May Warbler (*Dendroica tigrina*) in Alberta, by Michael Norton. 20 pages.

34. Status of the Whooping Crane (*Grus americana*) in Alberta, by Jennifer L. White. 21 pages.
35. Status of Soapweed (*Yucca glauca*) in Alberta, by Donna Hurlburt. 18 pages.
36. Status of the Harlequin Duck (*Histrionicus histrionicus*) in Alberta, by Beth MacCallum. 38 pages.

For copies contact the Information Centre - Publications, Alberta Environmental Protection, Natural Resources Service, Main Floor, Great West Life Building, 9920-108 Street, Edmonton, Alberta T5K 2M4, Canada (telephone: (780) 422-2079), OR Information Service, Alberta Environmental Protection, #100, 3115-12 Street NE, Calgary, Alberta T2E 7J2, Canada (telephone: (403) 297-3362); or visit web site at: <http://www.gov.ab.ca/env/fw/status/reports/index.html>

Point Pelee Natural History News 1(2) Summer 2001

This newsletter for Point Pelee, Ontario, is edited by Alan Wormington (e-mail: wormington@juno.com). Editorial Assistants are M. Lea Martell and Matthew J. Smith. The web site is www.wincom.net/~fopp/Natural_History_News.htm

ARTICLES: The Colonial Waterbirds of Middle Island, Western Lake Erie (D. V. "Chip" Weseloh — Noteworthy bird records: March to May 2001 (Alan Wormington) — Early Migration of Bonaparte's Gull at Point Pelee (Alan

Wormington — IN THE FIELD — UPCOMING EVENTS AND OUTINGS.

Subscription rates are Canada: CAN \$15 (one year) or \$30 (two years); International: US \$15 (one year) or \$30 (two years). Send payment (and e-mail address, optional) to The Friends of Point Pelee, 1118 Point Pelee Drive, Leamington, Ontario N8H 3V4. Issues will be mailed in March, June, September, and December, and back issues will be available for \$15 per Volume/ \$5 per issue (postage paid).

82nd Annual Meeting of the American Society of Mammalogists

The 82nd Annual Meeting of the American Society of Mammalogists will be held 15-19 June 2002 at McNeese State University, Lake Charles, Louisiana. In addition to contributed oral and poster presentations covering all aspects of mammalian biology, this year's program will feature two symposia. "Wildlife capture, handling and release: large and small" will be conducted by Mark Johnson DVM; "Macroecology of mammals: patterns, processes and possibilities" will be convened by Dawn M. Kaufman and Michael R. Willig. Special addresses will be offered by Drs. Timothy E. Lawlor (Joseph Grinnell awardee), and Theodore

Fleming (C. Hart Merriam awardee). Also included are the usual ASM socials, ideal for professional interaction.

Non-members who are interested in attending the meetings and/or presenting papers should request materials from the Chairman of the Local Program Committee, Dr. Gale Haigh (337-475-5667). For information regarding conference arrangements, contact Dr. Haigh or Dr. Greg Hartman (337-475-5672). Additional information and electronic registration is available at <http://www.mcneese.edu/asm2002>; for more information about the ASM, see their website at <http://www.mammalsociety.org>.

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The CANADIAN FIELD-NATURALIST

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada



Volume 115, Number 4

October-December 2001

The Ottawa Field-Naturalists' Club

FOUNDED IN 1879

Patrons

Her Excellency The Right Honourable Adrienne Clarkson, C.C., C.M.M., C.D.

Governor General of Canada

His Excellency John Ralston Saul, C.C.

The objectives of this Club shall be to promote the appreciation, preservation and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and cooperate with organizations engaged in preserving, maintaining or restoring environments of high quality for living things.

Honorary Members

Edward L. Bousfield
Donald M. Britton
Irwin M. Brodo
William J. Cody
Francis R. Cook
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Cover: Great Horned Owl (*Bubo virginianus*) holding a recently captured Richardson's Ground Squirrel (*Spermophilus richardsoni*) at 1315 h Mountain Standard Time on 17 July 1999 near Picture Butte, Alberta, Canada. Photograph courtesy of Gail R. Michener. See pages 543–548.

The Canadian Field-Naturalist

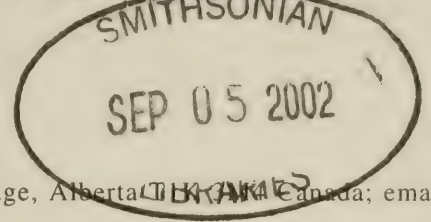
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Great Horned Owl, *Bubo virginianus*, Predation on Richardson's Ground Squirrels, *Spermophilus richardsonii*

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Michener, Gail R. 2001. Great Horned Owl, *Bubo virginianus*, predation on Richardson's Ground Squirrels, *Spermophilus richardsonii*. Canadian Field-Naturalist 115 (4): 543-548.

Although diurnal squirrels often form a minor component of the prey found in regurgitated pellets of Great Horned Owls, direct observation of the circumstances that result in a normally diurnal species appearing in the diet of a normally nocturnal predator is rare. During a long-term study of the behavioural ecology of Richardson's Ground Squirrels (*Spermophilus richardsonii*) in southern Alberta, I observed Great Horned Owls capture 14 adult ground squirrels in late February-early March and six juveniles in mid-summer. Temporal overlap between predator and prey occurred in two ways, through a shift toward twilight activity by estrous female and male ground squirrels during their mating season in spring and through a shift to daylight hunting by owls in summer. Twilight attacks were launched from the tops of objects such as grain augers and fence posts, whereas daylight attacks were launched from within the canopy of a tree.

Key Words: *Bubo virginianus*, diurnal hunting, Great Horned Owl, owl pellets, predator-prey relations, Richardson's Ground Squirrel, *Spermophilus richardsonii*.

Common mammalian prey items in the diet of Great Horned Owls (*Bubo virginianus*) range in size from mice (*Peromyscus*) and voles (*Microtus*) to rabbits (*Sylvilagus*) and hares (*Lepus*) (Houston et al. 1998). Although almost all sciurids fall within this size range, squirrels generally account for a minor fraction (usually <2% of prey items) of the diet of Great Horned Owls, even in areas where such squirrels are abundant (Weir and Hanson 1989) and form a major component of the diets of sympatric buteos (Fitch 1947; Craighead and Craighead 1956; McInville and Keith 1974; Gilmer et al. 1983). With the exception of the nocturnal flying squirrels (*Glaucomys*), other North American sciurids, whether tree-dwelling (*Sciurus*, *Tamiasciurus*) or ground-dwelling (*Tamias*, *Spermophilus*, *Cynomys*, *Marmota*), are diurnal. Great Horned Owls are generally crepuscular and nocturnal hunters (Marti 1974; Rudolph 1978), so the low representation of diurnal sciurids in the diet of Great Horned Owls is attributed to the minimal temporal overlap in times of day at which squirrels and owls are active (Jaksic and Marti 1984). Furthermore, most ground-dwelling squirrels in North America are hibernators, so are available to above-ground predators for only a portion of the year.

Descriptions of Great Horned Owl diets are rarely based on direct observation of hunting, but depend

primarily on analyses of regurgitated pellets and secondarily on prey remains at nests or in stomach contents. Diurnal hunting by Great Horned Owls has been inferred when ground-dwelling squirrels appear in pellets (Bent 1938, page 337; Fitch 1947, page 144), but the circumstances associated with such captures are unknown. Here I report observations of Great Horned Owls successfully hunting Richardson's Ground Squirrels (*Spermophilus richardsonii*) under two conditions, during evening twilight in the ground squirrels' mating season in late February-early March and in full daylight during summer in June and July.

Methods

Information on Great Horned Owl predation was obtained incidentally during a study of the behavioural ecology of Richardson's Ground Squirrels (Michener 1992, 1998, 2000) at a site located 5 km E and 1 km S of Picture Butte in southern Alberta, Canada (49°52'N, 112°43'W). The focus of the study was a 1.4-ha site inhabited by Richardson's Ground Squirrels, but squirrels also encroached into adjacent cultivated fields and a farm yard. Except for a solitary Narrow-Leaf Cottonwood (*Populus angustifolia*), hereafter referred to as the Lone Tree, the study site was open grassy habitat with no cover. In the adjacent

farm yard, equipment such as metal grain augers provided potential perches for owls. Great Horned Owls commonly nested and roosted in a shelter belt (predominantly cottonwoods *Populus* spp.) 200 m from the Lone Tree.

All Richardson's Ground Squirrels, both within the main site and in adjacent areas, were permanently marked with a metal tag in each ear. All adults and some juveniles were individually dye-marked for daily visual censusing throughout the active season from 1987 to 2000 and most adults were individually dye-marked in 2001. The number, age, and sex of squirrels active in the above-ground population varied seasonally (Michener 1998). Generally, adult (≥ 1 year old) male Richardson's Ground Squirrels emerged from hibernation in mid- to late February and adult females emerged in late February to mid-March. Females mated, usually in the late afternoon, 2–5 days after emergence from hibernation (Michener and McLean 1996), then gave birth underground 23 days later (Michener 1989). Litters (typically of 6–8 juveniles) first emerged above ground when 29–30 days old, in late April and early May. Adult males entered hibernation in early to mid-June, adult females in mid-June to early July, juvenile females in early to mid-August, and juvenile males in early to mid-October (Michener 1998). Squirrels were live-trapped at intervals throughout the active season to record body mass (Michener 1998).

Information on daily termination of diurnal activity of Richardson's Ground Squirrels was obtained by observing dye-marked animals retire into their sleeping burrows. Observations were made either from a farm house adjacent to the study site or wooden booths within the study site.

Because the focus of the study was on behaviour of ground squirrels, collection of data on the presence and activity of Great Horned Owls was usually limited to periods when owl activity overlapped with that of ground squirrels. However, in summer 2000, I scanned for the presence of Great Horned Owls at twilight. Additionally, when owls were known to be frequenting the site, searches for pellets were made beneath perches. Pellets were inspected, and fur and skeletal remains of Richardson's Ground Squirrels were identified with respect to reference specimens from the study site. Remains of other species were noted but not classified to species.

All times are reported as Mountain Standard Time (MST).

Results

Retirement times were known for Richardson's Ground Squirrels on 27 evenings between 17 March and 13 June 1996 and 59 evenings between 7 March and 3 July 1997. On average, retirement into the sleeping burrow occurred 70 ± 37 (SD) min before

sunset ($n = 86$ evenings on which retirement times were averaged for 5–12 adult females per evening). Ground squirrels tended to retire latest relative to sunset from mid-May to mid-June, but they still entered their sleeping burrows 35 ± 21 min before sunset ($n = 22$ evenings). In June, squirrels usually retired between 1940 and 2020 h MST. Consequently, a Great Horned Owl that arrived between 2045 and 2147 h (mean = 2111 h) and perched on grain augers on 16 evenings in June 2000 did not overlap with the active period of ground squirrels. In contrast, a Great Horned Owl that perched during the daytime in the Lone Tree on 20 of 43 observation days between 13 June and 12 August 1999 and on 4 of 17 observation days between 26 June and 16 July 2000 overlapped with the daily activity period of ground squirrels. The times of day at which the owl was first noted depended on concurrent studies of ground squirrels, but ranged from 0545 h to 1940 h MST. On at least seven days, the owl remained in the Lone Tree for minimum periods of 4–13 daylight hours. Only one Great Horned Owl, in adult plumage, was observed at any time in the Lone Tree; it was assumed to be the same individual throughout June to August 1999 and, given the similarity in behaviour, may have been the same individual in June and July 2000.

In the Lone Tree, the owl perched within the canopy, 4.25–5.75 m above the ground and 1.25–2.75 m below the highest point of the tree. In this location, the owl was partially or completely obscured by leaves and branches from most viewing angles and often blended against the bark on the tree trunk. Richardson's Ground Squirrels usually assume an upright alert posture or give alarm calls when a predator is nearby, but such behaviours were rarely given when the owl was in the Lone Tree, suggesting that ground squirrels either failed to detect the owl or habituated to its prolonged presence. On four days in 2000 when the owl's position in the Lone Tree enabled me to observe it with a telescope from 115 m away, it frequently (13/21 observations) either changed its orientation on the branch, moved its head, or had its eyes open, suggesting that the owl was visually scanning the site.

On three occasions, at 0700 h MST on 24 June 1999, 1842 h on 10 July 1999, and 0712 h on 5 July 2000, I witnessed a Great Horned Owl capture a Richardson's Ground Squirrel by swooping down from the Lone Tree to distances of 10–15 m. Additionally, I saw the owl in the Lone Tree holding a recently captured ground squirrel in its talons (see cover photograph) on three other days, at 1300 h on 17 July 1999, 1115 h on 27 June 2000, and 1510 h on 16 July 2000, and I saw it launch unsuccessful attack flights of 10–30 m from the Lone Tree on five other days. Following the witnessed captures, the owl remained on the ground grasping the prey in its talons

for several minutes before flying. After the first of these captures, the owl initially landed on nearby farm machinery, then in an adjacent crop field, before flying out of sight with the intact ground squirrel. After the other two witnessed captures, the owl took the prey back to the Lone Tree. Of the five ground squirrels carried to the Lone Tree, two were still intact when the owl flew with them in its talons to the nearby shelter belt on my approach after 15 and 60 min. The anterior end of the other three squirrels was partially eaten when I checked after 70, 105, and 270 min, confirming Errington's (1932) observation that captive Great Horned Owls given live ground squirrels regularly consumed the head first. The owl eventually flew off with the remaining carcass in its talons after the elapse of a further 230, 55, and 120 min, respectively, suggesting that consumption of an entire ground squirrel usually spans several hours or is delayed until nightfall. However, 105 min after the departure of the owl with prey on 24 June 1999, an owl (presumed to be the same individual, but without prey) perched in the Lone Tree and, 11 min later, attempted to capture another ground squirrel.

Adult male Richardson's Ground Squirrels had already entered hibernation by early June, and the mean \pm SD date of entry into hibernation for adult females was 18 June \pm 11 days ($n = 64$) in 1999 and 23 June \pm 11 days ($n = 73$) in 2000. The mean \pm SD date of birth for ground squirrels was 5 April \pm 6 days in 1999 ($n = 80$ litters) and 3 April \pm 7 days in 2000 ($n = 131$ litters). Consequently, when Great Horned Owls began frequenting the study site in late June, few adults were active and juvenile Richardson's Ground Squirrels were ≥ 10 weeks old and weighed ≥ 300 g (mean \pm SD mass: 360 \pm 54 g, $n = 38$, 3 July 1999; 348 \pm 60 g, $n = 46$, 6 July 2000). Based on pelage colour, all six of the ground squirrels I saw captured by Great Horned Owls in late June to mid-July were juveniles, of which one (a female) was individually identifiable from its dye mark.

I collected 10 Great Horned Owl pellets beneath the Lone Tree (eight pellets) and a grain auger 40 m from the tree (two pellets). Two pellets contained only ground squirrel remains, five pellets contained both ground squirrel and mouse remains, and three pellets contained only mouse remains. Five of the seven pellets with ground squirrel remains also contained either a single ear tag (four pellets) or a pair of ear tags (one pellet), positively identifying the Richardson's Ground Squirrels as three juvenile males and two juvenile females. The seven pellets all contained cranial elements and one or both dentaries of a Richardson's Ground Squirrel, and six pellets also contained 1–3 cervical vertebrae; no pellets included remnants of the appendicular skeleton of Richardson's Ground Squirrels. Two pellets collected on the same day contained mutually exclusive sets of similar-sized bones, so were assumed to rep-

resent two castings from the same ground squirrel. Another pellet contained the ear tag and remains of one of the observed kills. Adjusting for these pellets and allowing for the possibility that remains in some other pellets derived from ground squirrels seen captured before the pellet was collected, the minimum number of Richardson's Ground Squirrels represented by observed captures and in pellets in the summers of 1999 and 2000 was nine juveniles and the maximum was 11 juveniles.

In addition to diurnal hunting of Richardson's Ground Squirrels in June and July of 1999 and 2000, a Great Horned Owl was observed capturing ground squirrels after sunset during the squirrels' mating season in 1998 and 2001. The only time of year at which Richardson's Ground Squirrels remain active until sunset and later is during the mating season, when animals engage in courtship and copulation late in the day (Michener and McLean 1996). Males and estrous females retired, on average, at 1811 h MST between 22 February and 4 March 1998 (SD = 15 min, range: 1740–1840 h, $n = 37$ retirements on 10 evenings), whereas sunset occurred at 1800–1817 h during this period. During the next bout of mating activity, following a snowstorm, males and estrous females retired, on average, at 1838 h between 14 and 21 March (SD = 14 min, range: 1810–1859 h, $n = 31$ retirements observed on five evenings), whereas sunset occurred at 1833–1844 h. A Great Horned Owl arrived, on average, at 1836 h on six evenings from 24 February to 16 March 1998 and perched on fence posts, grain augers, or wooden booths. Four captures, assumed to be Richardson's Ground Squirrels from their size, were observed 22–34 min after sunset, at 1822 h MST on 24 February, 1845 h on 1 March, 1849 h on 3 March, and 1903 h on 15 March. Based on a combination of the known location of the capture and which individual was missing from that area the next morning, Great Horned Owls were assumed to have captured one adult female and three adult male Richardson's Ground Squirrels in 1998.

In conjunction with observations of Richardson's Ground Squirrels during the mating season in 2001, a particular effort was made to monitor the behaviour of Great Horned Owls every evening from 3 to 19 March, the period during which 97% of females mated, and to videorecord predation events when light levels permitted. Female Richardson's Ground Squirrels rarely copulated before 1745 h, and those females that copulated with a second male usually did so after 1830 h. Although most copulations occurred below ground, courtship behaviours occurred above ground and squirrels usually resurfaced after termination of underground copulations before finally retiring for the night.

A Great Horned Owl perched on the study site on 14 of the 17 evenings from 3 to 19 March 2001. Only

a single owl was seen on any evening, and it arrived between 1838 and 1905 h MST (mean arrival time = 1851 h, SD = 9 min, $n = 13$ evenings with recorded times), on average 21 min after sunset (SD = 6 min, range: 6–29 min, $n = 13$). Except for one evening with no attempts to capture prey on site, the owl was successful on each of the other 13 evenings, with captures of 10 Richardson's Ground Squirrels, one vole or mouse, and two prey that could not be identified due to low light levels. Of evenings with confirmed capture of a squirrel, the owl was successful on either its first ($n = 5$ evenings) or second attempt ($n = 5$). Average elapsed time between arrival of the Great Horned Owl and capture of a Richardson's Ground Squirrel was 11 min (SD = 4 min, range: 2–16 min, $n = 9$ evenings with recorded times). Captures occurred, on average, at 1859 h (SD = 9 min, range: 1848–1918 h, $n = 9$), 30 ± 6 min after sunset. Of 10 successful attacks, eight were launched from metal grain augers (heights = 3.32–4.13 m), one from a wooden booth (height = 2.14 m), and one from a wooden fence post (height = 1.15 m); although the Lone Tree was the tallest object on the site, it was never used to launch twilight attacks on squirrels. The average distance between the perch from which successful attacks were launched and the capture point was 41 m (SD = 28 m, range: 14–94 m, $n = 10$). Except for one capture on which the owl scooped up the ground squirrel in its talons and flew off without landing, the Great Horned Owl remained on the ground at the capture site, grasping the Richardson's Ground Squirrel in its talons while occasionally pecking and tugging with the beak. After 0.7–2.7 min on the ground, the owl then flew 125–238 m ($n = 6$ evenings when light levels permitted visual tracking), landed briefly on a wooden booth or on irrigation equipment in an adjacent field before finally flying out of sight still carrying the squirrel in its talons. The 10 witnessed captures included two squirrels of unknown identity that resided in peripheral locations, one male, and seven estrous female Richardson's Ground Squirrels. Thus, of 13 female squirrels known to have disappeared within one week of their emergence from hibernation, owl predation accounted for at least 54% of those losses. Mean \pm SD mass of the eight individually identified Richardson's Ground Squirrels, based on weights obtained 1–3 days before capture by the owl, was 269 ± 63 g (range: 195–395 g). Although a Great Horned Owl continued to frequent the site in the evenings in late March, after the squirrels' mating season had terminated, Richardson's Ground Squirrels were no longer available as prey because they all retired before sunset.

Discussion

Successful hunting by owls requires overlap of the active periods of both predator and prey (Reynolds

and Gorman 1999). Consequently, the most commonly reported mammalian prey of Great Horned Owls in North America are nocturnal species such as *Lepus*, *Sylvilagus*, *Neotoma*, *Thomomys*, *Sigmodon*, *Dipodomys*, *Microtus*, and *Peromyscus* (Fitch 1947; Korschgen and Stuart 1972; Marti 1974; McInville and Keith 1974). Diurnal hunting has been inferred from daylight activity by Great Horned Owls and from remains of diurnal species in pellets or at nests (Sherman 1912; Dixon 1914; Bent 1938; Fitch 1947; Vaughan 1954; Maser and Brodie 1966). Although ground squirrels (*Spermophilus*) are frequently reported to form a minor component of the diet of Great Horned Owls (Bird 1929; Hamerstrom and Mattson 1939; Errington et al. 1940; Alcorn 1942; Fitch 1947; Orians and Kuhlman 1956; Seidensticker 1968; Maser et al. 1970; McInville and Keith 1974; Gilmer et al. 1983; Jaksic and Marti 1984; Knight and Jackman 1984; Zimmerman et al. 1996; Murphy 1997; Rohner et al. 2001), direct information on the circumstances that result in a normally diurnal species appearing in the diet of a normally nocturnal predator is rare. My observations establish that temporal overlap between Richardson's Ground Squirrels and Great Horned Owls occurred in two ways, through a shift toward twilight activity by squirrels during their mating season in spring, the only time of year at which this otherwise strictly diurnal sciurid is active after sunset, and through a shift to daylight hunting by owls in summer.

Seidensticker (1968) reported that Richardson's Ground Squirrels accounted for 42 of 774 prey items (5.4%) in three collections of Great Horned Owl pellets gathered in southern Montana, whereas McInville and Keith (1974) found that Richardson's Ground Squirrels were rarely fed to Great Horned Owl chicks in central Alberta despite their commonness in the diets of sympatric Red-tailed Hawks (*Buteo jamaicensis*). If, as my observations suggest, ground squirrels tend to be captured only at certain periods within their active season, representation in the diet is likely to vary seasonally even in areas where some owls hunt ground squirrels. Vulnerability of ground squirrels to predation by Great Horned Owls also may vary with species and locale. Richardson's Ground Squirrels and Arctic Ground Squirrels (*S. parryi*) mate in the late afternoon (Michener and McLean 1996; Lacey et al. 1997), and thus may be at risk from predation at twilight in spring, whereas those species of ground-dwelling squirrels that mate in the morning or early afternoon (Murie 1995; Hoogland 1998) may be less at risk. At the northern limit of the geographic range of Great Horned Owls, where owls prey heavily on Snowshoe Hares (*Lepus americanus*) and summer daylight is lengthy, Arctic Ground Squirrels form a consistent component of owl diets (usually about 5% of prey items) and can account for 12–22% of prey biomass

in years with low population density of hares (Rohner et al. 2001).

Great Horned Owls are perch-and-pounce hunters (Houston et al. 1998) that usually perch on tall, often isolated, vantage points when foraging (Marti 1974; Rudolph 1978). Owls that hunted on my site after sunset perched on exposed objects, both in spring and summer. Even when perched in conspicuous locations, owls are likely not conspicuous to ground squirrels under twilight conditions because ground squirrels have a pigmented eye lens and cone-dominant retina (Yolton et al. 1974; Jacobs 1978). Indeed, by remaining active after sunset during the mating season, estrous female and male Richardson's Ground Squirrels were particularly vulnerable to predation, to the extent that an owl hunting during the squirrels' mating season in 2001 was able to capture a squirrel almost every evening within a few minutes of its arrival. During summer daylight, when visual acuity is high for ground squirrels, Great Horned Owls perched inconspicuously within the canopy of a tree. Sovern et al. (1994) suggested that diurnal hunting of chipmunks (*Tamias*) by Spotted Owls (*Strix occidentalis*) was an opportunistic response to prey detected while owls were roosting. Hunting of Richardson's Ground Squirrels on my study site in summer may initially have been an incidental outcome of the choice of a daytime roost, but repeated use of the tree and visual scanning suggest a deliberate hunting strategy by at least one Great Horned Owl. The range of capture times in summer (0700–1842 h MST) indicates that responsiveness to potential prey occurred throughout the daylight hours.

Great Horned Owls have a long-standing reputation (e.g., Errington 1932; Houston et al. 1998) as versatile predators. Bosakowski et al. (1989) noted that the diet of Great Horned Owls nesting in deciduous forests in north-eastern USA included more birds and fewer lagomorphs than is typical in more open habitats, and they reported that two species of diurnal arboreal squirrels (*Sciurus carolinensis* and *Tamiasciurus hudsonicus*) formed 10% of prey items. Bosakowski et al. (1989) did not discuss diurnal hunting, but Packard (1954) noted Great Horned Owls striking the leaf nests of Fox Squirrels (*S. niger*) during daylight, sometimes flushing squirrels from the nest. My observations of twilight hunting of Richardson's Ground Squirrels in the squirrels' mating season in spring and daylight hunting throughout the day in summer confirm the categorization of Great Horned Owls as flexible hunters by describing two more circumstances in which diurnal squirrels appear in the diet.

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Inability to Predict Geographic Origin of Yellow-headed Blackbirds, *Xanthocephalus xanthocephalus*, During Migration

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Yellow-headed Blackbirds (*Xanthocephalus xanthocephalus*) collected at different breeding locations in Alberta, Saskatchewan, Manitoba, and North Dakota exhibit clearly discernable morphometric differences with larger bodied birds found at more northern and western locations. We reduced eight skeletal measurements and body length from adult female and male Yellow-headed Blackbirds to their first two principal components. Principal component scores progressively increased at more northwestern locations. Principal component scores were also derived from measurements of birds collected in central North Dakota throughout summer and fall. We hypothesized an increase in principal component scores of Yellow-headed Blackbirds from summer through fall within central North Dakota as larger bodied migrants arrived and displaced local breeding birds. However, we were unable to detect such an increase in principal component scores from mid-June through mid-September over two years of study. Discriminant models that were developed to distinguish birds breeding in Canada from those breeding in the USA were thus poor predictors of the migratory status of Yellow-headed Blackbirds. Consequently, we were unable to exploit the morphometric differences inherent among Yellow-headed Blackbirds breeding at different geographic locations to quantify the timing or the magnitude of their migration through central North Dakota.

Key Words: Yellow-headed Blackbird, *Xanthocephalus xanthocephalus*, principal component analysis, Alberta, Saskatchewan, Manitoba, North Dakota, morphology, migration.

Identification of the patterns, timing, and duration of migration for passerine birds has been hindered by an inability to identify the origin or destination of birds encountered during migration. Historically, encounters with banded birds have been used to ascertain migration routes and the timing of migration (e.g., Royall et al. 1971; Dolbeer 1982). However, encounters of banded birds are rare. Encounters at two locations within the same year, that may elucidate the timing of migration, are even rarer. Indeed, only 246 of 40 855 Yellow-headed Blackbirds banded between 1937 and 1968 were subsequently encountered, and only 36 of these were direct recoveries at separate locations during the same year (Royall et al. 1971). Encounters of banded birds, however, can be markedly increased if bands are accompanied by auxiliary markers that can be detected without the recapture of individuals (Bray et al. 1977).

Mass-marking of birds at en-route migration roosts using aerially applied micro-tags or dyes (Linz et al. 1991) has been successfully employed to mark large numbers of migratory birds (Otis et al. 1986) that were subsequently encountered at breeding or wintering localities (Knittle et al. 1987). Even with this vastly increased efficiency in marking birds, recovery rates of marked birds remained relatively low. For example, Knittle et al. (1987) found

that only 770 of 8880 Red-winged Blackbirds (*Agelaius phoeniceus*) collected at breeding localities across the northern Great Plains had been marked during mass-marking of blackbirds at en-route roosts during spring.

An alternative to physically marking individual birds is to use their inherent morphometric or genetic variation to discern their geographic origin or destination. If geographically distinct subpopulations can be identified among breeding sites, these data could be used to identify the geographic origin of individuals encountered elsewhere. Indeed, morphometric data have been used to suggest breeding location of species encountered on wintering grounds (Ramos and Warner 1980) and during migration (James et al. 1984; Atwood 1989; Linz et al. 1993). Inability to assign individuals of widely distributed, panmictic species to subspecies or races — either through morphometric or genetic techniques — has hampered the development of these methods in the study of migration. However, both morphometric (Zink and Remsen 1986; Aldrich and James 1991) and genetic (Zink et al. 1987) techniques have been successfully employed in assessing geographic variation within otherwise monotypic species.

Yellow-headed Blackbirds (*Xanthocephalus xanthocephalus*) breeding on the northern Great Plains of North America exhibit discernable clinal variation

in morphology: larger bodied birds with relatively shorter limbs breed at more northern and western locations (Twedt et al. 1994). We attempted to exploit these inherent morphological differences to infer the geographic origin of individuals that were encountered during migration. Our objective was to determine if and when Yellow-headed Blackbirds that breed within central North Dakota are displaced by migrants.

Methods

From 28 May to 16 June 1987 and from 14 May to 17 June 1988, we collected adult male and female Yellow-headed Blackbirds within breeding locales in Alberta, Saskatchewan, Manitoba, and North Dakota as part of a study on geographic variation (Twedt et al. 1993, 1994). Because after-second-year males can easily be distinguished from second-year males under normal field conditions and because few second-year males hold breeding territories, we only collected after-second-year males during May and June. Additionally, we collected adult male and female Yellow-headed Blackbirds within Benson, Ramsey, and Wells Counties in central North Dakota (48° 01' N, 99° 40' W) between 21 June and 18 September during 1987 and 1988 for studies on diet (Twedt et al. 1991) and molt (Twedt 1990). Because after-second-year males cannot be separated from second-year males by plumage characteristics after their pre-basic molt is completed in mid-summer, we collected both adult age classes after 1 July.

From collected Yellow-headed Blackbirds, we recorded 13 morphometric measurements (Twedt et al. 1994). Collection site locations, methods of skeletal preparation, and measurement procedures were described by Twedt (1990). Because pre-basic molt and pre-migratory fat deposition during late summer result in temporal changes in mass, wing chord, total length, and tail length, we dropped all morphometric variables that were temporally unstable (Twedt and Linz 2002). However, we derived one additional measurement — body length. Body length was the difference between total length and tail length. Both total length and tail length were temporally unstable due to loss and re-growth of the tail during molt. However, because their difference negated this temporal instability, body length was temporally stable.

Using principal components analysis in SAS (SAS Institute 1989) we reduced body length and eight temporally stable skeletal measurements (skull width, and lengths of skull, keel, ulna, humerus, femur, tarsus, and tibiotarsus) to their principal components. Sex-specific principal components were obtained separately for birds collected at breeding locations and for birds collected in central North Dakota during summer and fall. Before deriving principal components, we replaced missing data that

resulted from broken or deformed bones (4% of total data) using regressions against the most highly correlated variables (Chan et al. 1976). To assess the relationship between these morphometric measurements and date of collection, we plotted principal component scores against date of collection. We reduced the variation among collection dates by constructing 5-day running-averages. These 5-day running averages were subjected to regression analysis to relate collection date to principal component scores. Finally, we discriminated between hypothesized subpopulations in Canada and the USA using discriminant analysis.

Results

We collected 176 female and 1481 male Yellow-headed Blackbirds from breeding locations across the northern Great Plains (Twedt et al. 1994). An additional 624 females and 865 males were collected after 21 June from central North Dakota. The first two principal components derived from morphometric measurements were consistently, biologically interpretable among sexes and seasons. The first principal component (PC 1) represented generalized size whereas PC 2 represented the birds' shape by contrasting axial dimensions with appendicular dimensions (Table 1). Generally, PC 3 contrasted skull and body measurements but varied slightly in interpretation among sexes and seasons. Because of similarity in interpretation between seasons, we present sex-specific principal component scores for combined data from all collected birds. We restricted further analyses to PC 1 and PC 2 within each sex. These first two principal components accounted for 68% and 61% of the variability in females and males, respectively (Table 1).

Multivariate analysis of variance of principal component scores detected significant differences among breeding locations ($F_{4, 344} = 7.04$, $P < 0.01$ female; $F_{6, 2952} = 46.2$, $P < 0.01$ male). Principal component scores from central North Dakota were negative but became increasingly positive at more northern and western locations as larger bodied birds with relatively shorter appendages were encountered (Table 2). Thus we hypothesized that migrants encountered in central North Dakota, that had originated in more northwestern breeding locations, would have greater PC scores than did Yellow-headed Blackbirds that bred in North Dakota.

To examine the hypothesis of increasing PC scores over time, we plotted 5-day running averages of PC scores against dates of collection (Figure 1). Although average PC scores derived from female measurements slightly increased over time, the slope of neither PC 1 nor PC 2 differed significantly from zero ($t > 1.19$, $P > 0.21$). Similarly, PC scores for males exhibited no significant trend over time ($t > 1.58$, $P > 0.12$).

TABLE 1. Principal component (PC) loadings on nine temporally stable variables for Yellow-headed Blackbirds.

Variable	PC loadings					
	PC 1		PC 2		PC 3	
	Female	Male	Female	Male	Female	Male
Body length	0.105	0.157	0.441	0.617	0.831	-0.577
Skull length	0.236	0.261	0.480	0.392	-0.475	0.009
Skull width	0.214	0.164	0.670	0.542	-0.202	0.767
Keel length	0.357	0.244	-0.153	0.184	-0.038	-0.273
Femur length	0.381	0.424	-0.074	-0.155	-0.032	0.009
Tarsus length	0.415	0.419	-0.175	-0.160	0.028	0.007
Tibiotarsus length	0.413	0.436	-0.186	-0.158	0.023	-0.012
Humerus length	0.421	0.370	-0.180	-0.178	0.029	0.019
Ulna length	0.309	0.371	0.015	-0.177	0.196	0.055
Eigenvalue	5.03	4.40	1.09	1.06	0.95	0.86
% variance explained	55.9	48.9	12.1	11.7	10.5	9.6
Cumulative variance	55.9	48.9	68.0	60.6	78.5	70.2

Because a previous analysis (Twedt et al. 1994) detected two discernable subpopulations within the overall morphometric cline exhibited by Yellow-headed Blackbirds, we attempted to predict membership in these subpopulations using discriminant analysis. We first used stepwise discriminant analysis to reduce the number of morphometric variables to four for females (body length, skull length, humerus, and femur) and five for males (body length, skull length, skull width, keel, and tibiotarsus). Using birds collected at breeding locations and discriminating between birds breeding in Canada and those breeding in the USA, the four variable discriminant model for females had a 0.70 ($CI_{90\%} = 0.65\text{--}0.75$) probability of correctly classifying birds (i.e., 70% of birds were correctly classified to their collection location). Similarly, the five variable model we used for males had a 0.68 ($CI_{90\%} = 0.66\text{--}0.70$) probability of correct classification. Kappa statistics (Titus et al. 1984) for both female and male models were significantly greater than zero ($\kappa > 0.35$, $SE_{\kappa} < 0.11$, $z > 3.37$, $P < 0.01$) which indicated that both models predicted significantly better than chance.

When we applied these discriminant models to Yellow-headed Blackbirds collected in central North Dakota during summer and fall, we classified 232 of 601 females and 190 of 936 males as migrants (i.e.,

birds with geographic origins to the northwest of the collection location). The proportion of migrants within 5-day collection periods ranged from 0.09 to 0.59 for females and from 0.04 to 0.39 for males (Figure 2). However, regression slopes of the proportion of migrants against time did not differ from zero ($t = 1.376$, $P = 0.17$) for females and had a significant negative slope ($t = -4.857$, $P < 0.01$) for males.

Discussion

We were unable to detect our hypothesized increase in principal component scores over time within central North Dakota. Indeed, average PC scores tended to decrease slightly from June through September. Discriminant models constructed to distinguish birds breeding in Canada from those breeding in the USA similarly were unable to detect trends in the migratory status of Yellow-headed Blackbirds in central North Dakota. Failure of these models was likely, in part, due to their relatively poor ability to discriminate between local breeding birds and birds breeding at more northwestern locations — only 70% of birds could be correctly classified. In fact, the inferred proportion of migrants that resulted from application of our discriminant models remained constant or declined during summer and fall. Neither of these

TABLE 2. Mean principal component scores for Yellow-headed Blackbirds collected at breeding locations during 1987 and 1988.

Location	PC 1		PC 2	
	Female	Male	Female	Male
Alberta and western Saskatchewan	0.546	0.751	0.365	0.205
Central Saskatchewan	0.143 ^a	0.573	-0.078 ^a	0.065
Southern Saskatchewan and Manitoba		-0.015		0.206
Central North Dakota	-0.822	-0.909	-0.341	-0.339

^aIncludes all females collected in Saskatchewan and Manitoba.

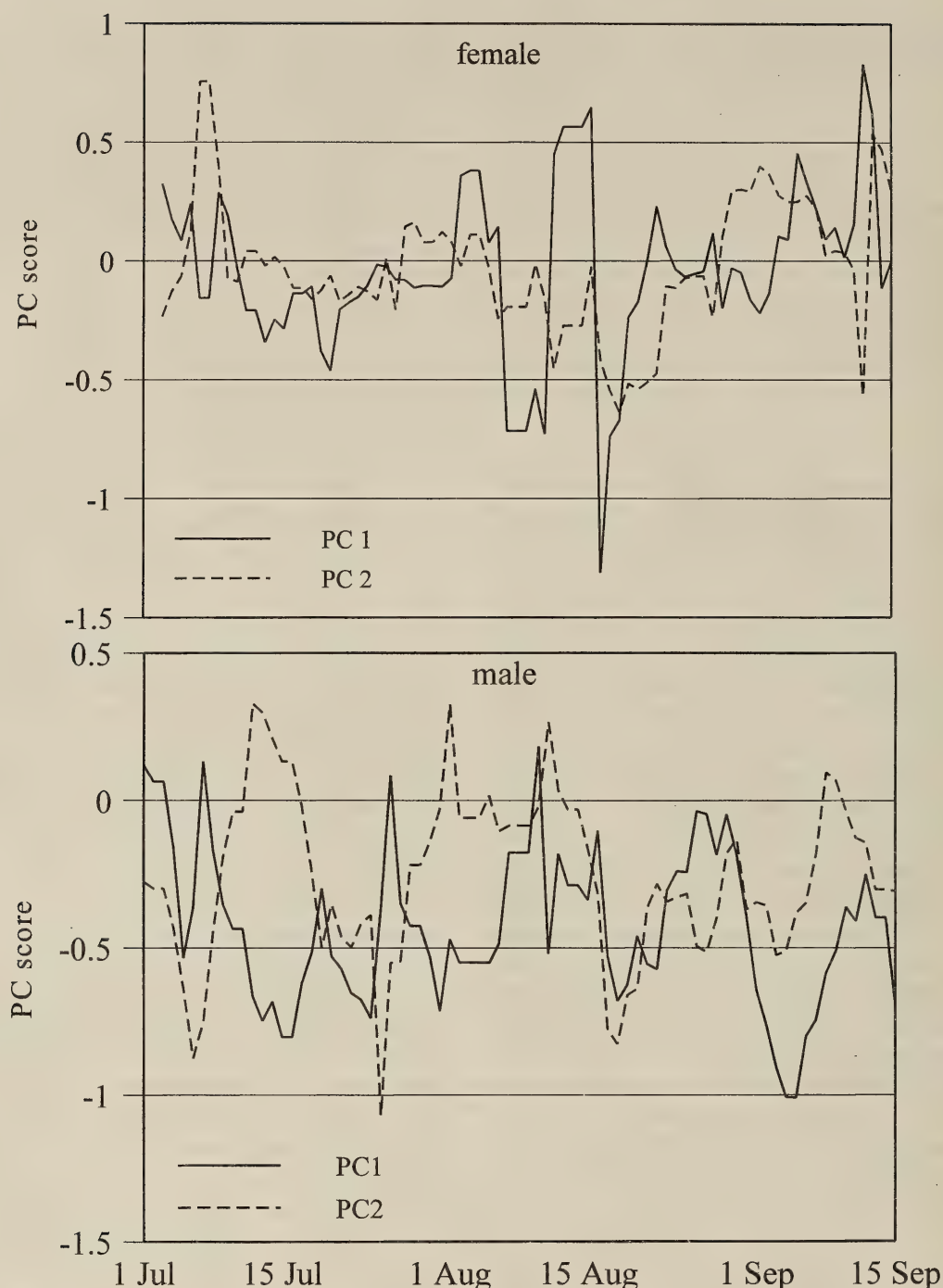


FIGURE 1. Five-day running average of principal component (PC) scores derived from 8 skeletal mensurations and body length of Yellow-headed Blackbirds collected in central North Dakota during 1987 and 1988. For any 5-day period, mean sample sizes were 63 (range 7–172) for females and 55 (range 7–161) for males.

scenarios conformed with our hypothesis of an increase in the proportion of migrants over time.

Several possible explanations could account for our inability to detect late-summer migrants passing through central North Dakota. Most likely, our principal component and discriminant function models had insufficient power to discriminate along the morphometric cline exhibited by Yellow-headed Blackbirds. Our ability to detect migrants may have also been hindered by a failure of migrants to displace locally breeding birds but instead congregating

in heterogeneous populations within central North Dakota throughout late summer.

Alternatively, despite data from returns of banded birds that indicate a southeasterly migration route is used by Yellow-headed Blackbirds, it is possible that most migrants passing through our central North Dakota study area may have originated in more proximate locations in southern Manitoba and eastern Saskatchewan. Populations within these relatively nearby breeding locations share greater morphometric similarity with birds breeding in central

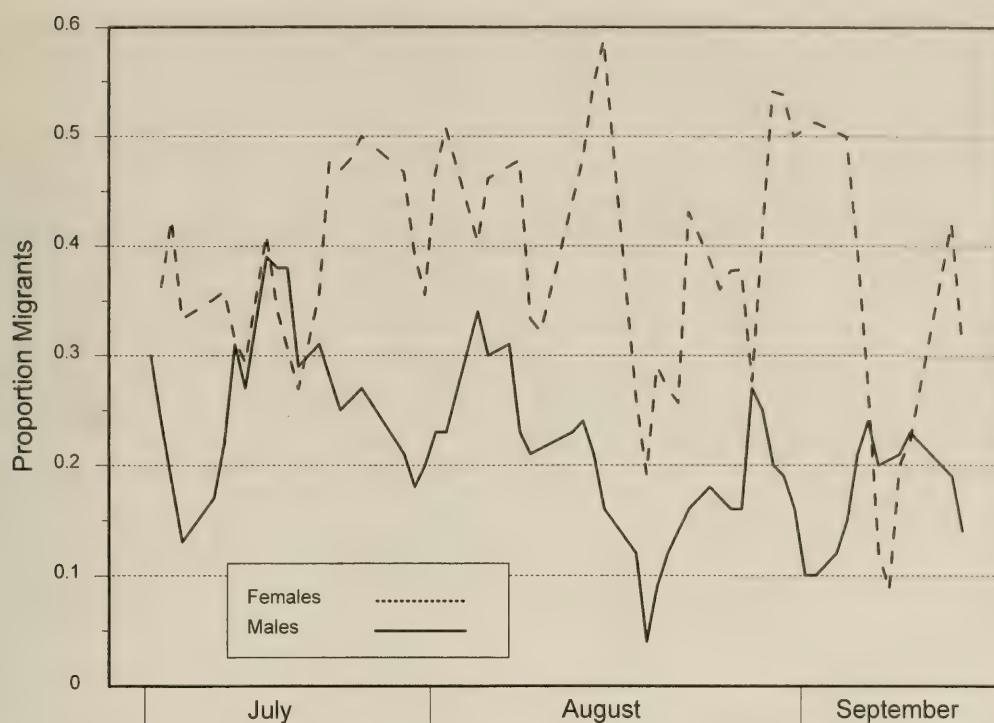


FIGURE 2. Proportion of male and female Yellow-headed Blackbirds classified as migrants in central North Dakota during 1987 and 1988. Plotted proportions are running averages based on 5-collection-day samples. Mean sample sizes were 54 (range 15–134) for females and 78 (range 29–166) for males.

North Dakota (Twedt et al. 1994), thereby increasing the difficulty of distinguishing differences between these populations using either principal components analysis or discriminant function analysis.

In summary, although distinct morphometric differences exist between Yellow-headed Blackbirds breeding in central North Dakota and those breeding at more northwestern locations in Canada, we were unable to exploit these differences to elucidate either the duration or magnitude of migration through central North Dakota. Unless refinement of these morphometric techniques can be achieved, it appears that elucidating migratory movements of this species will continue to rely on physically marking individual birds or the development of improved genetic markers.

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Review of the Status of the Northern Abalone, *Haliotis kamtschatkana*, in Canada†

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Jamieson, G. S. 2001. Review of the status of the Northern Abalone, *Haliotis kamtschatkana*, in Canada. *Canadian Field-Naturalist* 115(4): 555–563.

The Northern Abalone (*Haliotis kamtschatkana*) is the only abalone species in Canada and is widely distributed along the entire outer coast of British Columbia. In the late 1970s and 1980, there was a commercial fishery, but following a peak in landings in 1978–1979, landings rapidly declined. Its distribution in commercially exploitable concentrations is patchy, making stock assessments difficult to conduct. However, in the late 1980s, consistently low estimated abundance levels and increasing evidence for a substantial illegal harvest of abalone raised conservation concerns, resulting in aboriginal, recreational and commercial fisheries closures in 1990. Studies in other abalone species suggest that abalone larvae disperse over relatively short distances. If true for Northern Abalone as well, then this species may be particularly vulnerable to localised extirpations. Through the 1990s, there was no evidence of significant Northern Abalone recruitment along Canada's Pacific coast, and because of a high price, abalone poaching is still occurring. Expansion in the range of Sea Otters (*Enhydra lutris*), a major abalone predator, is also increasing natural mortality. Given these circumstances, a COSEWIC status of "threatened" was recommended.

Key Words: Northern Abalone, *Haliotis kamtschatkana*, British Columbia, distribution, stock status.

Jamieson (1989) reviewed the status of Northern, or Pinto, Abalone, *Haliotis kamtschatkana* Jonas, 1845, along the coast of British Columbia, Canada, but while the paper was accepted and reviewed by COSEWIC in April, 1988, no status could be assigned as COSEWIC at that time had no mandate to assess invertebrates. COSEWIC's mandate changed in 1994, however, and COSEWIC is now able to assign status to molluscs. Here, I review the current status of this species, and note changes in abundance and fisheries management which have occurred since my first report (Jamieson 1989). That report included sections on Northern Abalone general biology, limiting factors and special significance that are still relevant, and so are not repeated here.

The Northern Abalone (Figure 1) is the world's northernmost abalone species. Although eight abalone species occur in the Northeast Pacific off California (Cox 1962), there is only one species in the marine waters of Washington State, British Columbia, and Alaska. McLean (1966) provided the following description for it: "Shell relatively small, thin, elongate-oval, low. Open holes 3 to 6, on tubular projections. Broad channel present on the body whorl between the suture and row of holes. Sculpture of irregular bumps superimposed over spiral sculpture of broad ribs with weak spiral ribs in interspaces. Colour mottled reddish or greenish with areas of white or blue. Shell margin narrow. Muscle scar lacking, interior pearly white with faint iridescence of pink and green." British Columbia speci-

mens differ from Californian specimens in not having a broad channel in the body whorl and in having a less complex distribution of lumps in the spiral sculpture and a muscle scar on the anterior of some shells (McLean 1966).

Distribution

As noted by Sloan and Breen (1988) and Jamieson (1989), the Northern Abalone is found from Sitka Island, Alaska (57° N; Paul and Paul 1981) to Turtle Bay, Baja California (27.5° N; McLean 1966). In central California, the typical form merges into the subspecies *Haliotis kamtschatkana assimilis* Dall (Threaded Abalone), which occupies the southern part of the range (McLean 1966). The type locality for *Haliotis kamtschatkana*, "near Unalaska, Kamchatka Sea", is evidently in error since there are no records of *Haliotis* occurring at any point along the Aleutian Islands (McLean 1966). At its northern range limit, the Northern Abalone occurs from the lower intertidal zone to a depth of at least 100 m, whereas near its southern range limit, it is strictly subtidal, with most individuals occurring at depths between 10 to 20 m (McLean 1966). In British Columbia, most of the adult population is found at < 10 m depth (Mottet 1978). Northern Abalone prefer a firm substrate, usually rock, and are generally found in areas of moderate water exchange, such as occurs on exposed or semi-exposed coasts. They are patchily distributed within this habitat.

Habitat

There is no indication that there has been any permanent physical deterioration in Northern Abalone

†Threatened status assigned by COSEWIC in April 1999.

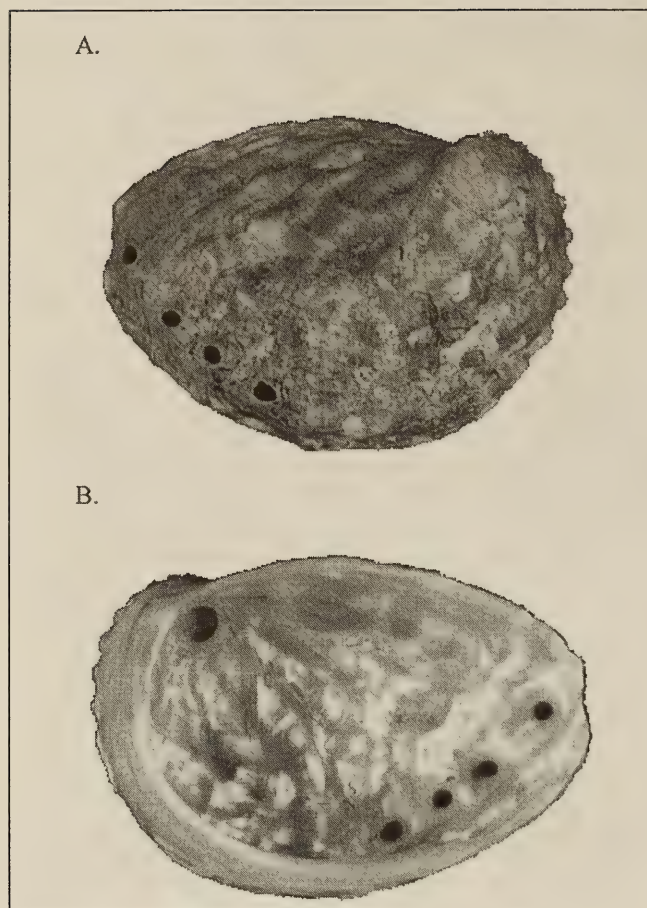


FIGURE 1. Northern Abalone shells. A. dorsal view. B. ventral view.

habitat in British Columbia over time. Fluctuation in biotic factors such as food availability and predators may vary substantially on a local scale, and catastrophes such as oil spills and human-induced, increased sedimentation can have short-term deleterious consequences. In British Columbia, greatest deterioration in marine water quality or disruption of substrate by either industry or urbanisation has occurred in sheltered waters (e.g., harbours), either around estuaries or in the Strait of Georgia. Northern Abalone are not greatly affected by this as they prefer cool, exposed waters. However, the eradication of Sea Otters (*Enhydra lutris*) in the late 1800s through hunting had ecosystem implications that likely affected abalone. Herbivorous prey items of Sea Otters, notably sea urchins (*Strongylocentrotus* spp.) and abalone, likely subsequently increased dramatically in abundance. This increase resulted in the establishment of "sea urchin barrens", which are large areas populated with urchins and virtually devoid of marine macroalgae. Sea urchins and Northern Abalone may compete for food, resulting in food-limited environments where abalone growth can be stunted (stunted abalone are locally called "surf" abalone) and larval dispersal from local populations can be reduced. When "surf" abalone are transplanted to kelp-abundant habitats, they commence grow-

ing again (Emmett et al. 1988), suggesting that food limitation can result in growth rate reduction.

Historical First Nation Utilisation

Diversity was a key to sustainable resource use by coastal First Nations peoples. Along with other species, abalone were used for food and the shells were used for decoration and as currency (Turner 1997). Virtually all areas of the land, water and shoreline fell under the specific "ownership" of one individual, usually a hereditary chief, who, while the recipient of the benefits of using the area, also had the responsibility of maintaining and sustaining the resources and sharing them equitably among other community members. All productive areas were closely watched and managed to ensure resource sustainability because the availability of species such as abalone directly affected the survival of these hunter-gatherers. There is no documented evidence that Canadian indigenous peoples dove for abalone, so the abalone that were harvested came only from the intertidal or shallow subtidal zones (Campbell 2000). The lack of diving limited the ability of native peoples to exploit abalone concentrations extensively, as most abalone concentrations occur at a depth of 0 to 10 m in high wave-energy areas (Sloan and Breen 1988). Historically, most waters deeper than 1 m would have functionally represented a natural abalone refugium from human harvesting (Jamieson 2000).

Historically, the major predator of adult abalone was the Sea Otter, not humans, as abalone are a preferred prey of these otters (Johnson 1982; Estes and Van Blaricom 1985). However, because native people hunted Sea Otters as well as abalone and Sea Otters likely avoided the immediate areas around native villages (Russ Jones, Haida Fisheries Program, Skidegate, British Columbia, personal communication). Coastal human habitations were historically relatively abundant along the coast, as indicated by the many coastal middens that can be seen today, and their presence may have created many refugia from Sea Otters where abalone could have occurred in at least modest abundance subtidally. Both Sea Otters and indigenous human populations were devastated almost simultaneously in the early 1800s by the arrival of Europeans, the former by hunting and the latter by diseases such as smallpox.

Population Size and Trends

Sloan and Breen (1988) and Jamieson (1989) both described factors influencing the abundance of abalone in British Columbia up until the mid-1980s. Campbell (2000) has summarised Northern Abalone stock status in British Columbia more recently. Briefly, the suggested relatively high abundance of abalone in the early 1970s (Figure 2) may have been influenced by both the absence at that time of sig-

nificant abalone fisheries and the eradication of Sea Otters. In areas where Sea Otters have been re-introduced in British Columbia, almost all surviving abalone are found only in rock crevices, whereas outside the range of Sea Otters, abalone are abundant on open rock faces outside crevices (Hines and Pearse 1982; Watson 1993). It is hypothesised that after Sea Otters were eradicated and First Nations peoples decreased by disease, abalone populations may have increased substantially in abundance by moving into more open habitats. The potentially numerous, albeit likely small, and geographically isolated abalone populations that might have existed along the coast would have been released from major predation pressures and may have gradually expanded in both size and number to ultimately support the recent commercial fisheries.

The modern industrial (i.e., export) abalone fishery began in British Columbia around 1975. Surveys of abundance have been conducted since 1978 (Table 1). Reported annual landings peaked in 1977 to 1978 at around 400 t (Figure 2), before being reduced by a quota to 226.8 t in 1979 and 113.4 t in 1980. Quotas continued to be reduced until they levelled out at 47.2 t from 1985 to 1989. At the time, any smaller quota was considered to be impractical, as existing limited-entry fishers would then be unable to make a desirable living. The only other option was fishery closure. Although efforts were being made to manage the fishery to a sustainable level of production, there were little data to indicate what this level might actually be. The abundance of legal-size abalone may have declined by as much as 60 to 90% by 1978 (Sloan and Breen 1988) and by the end of

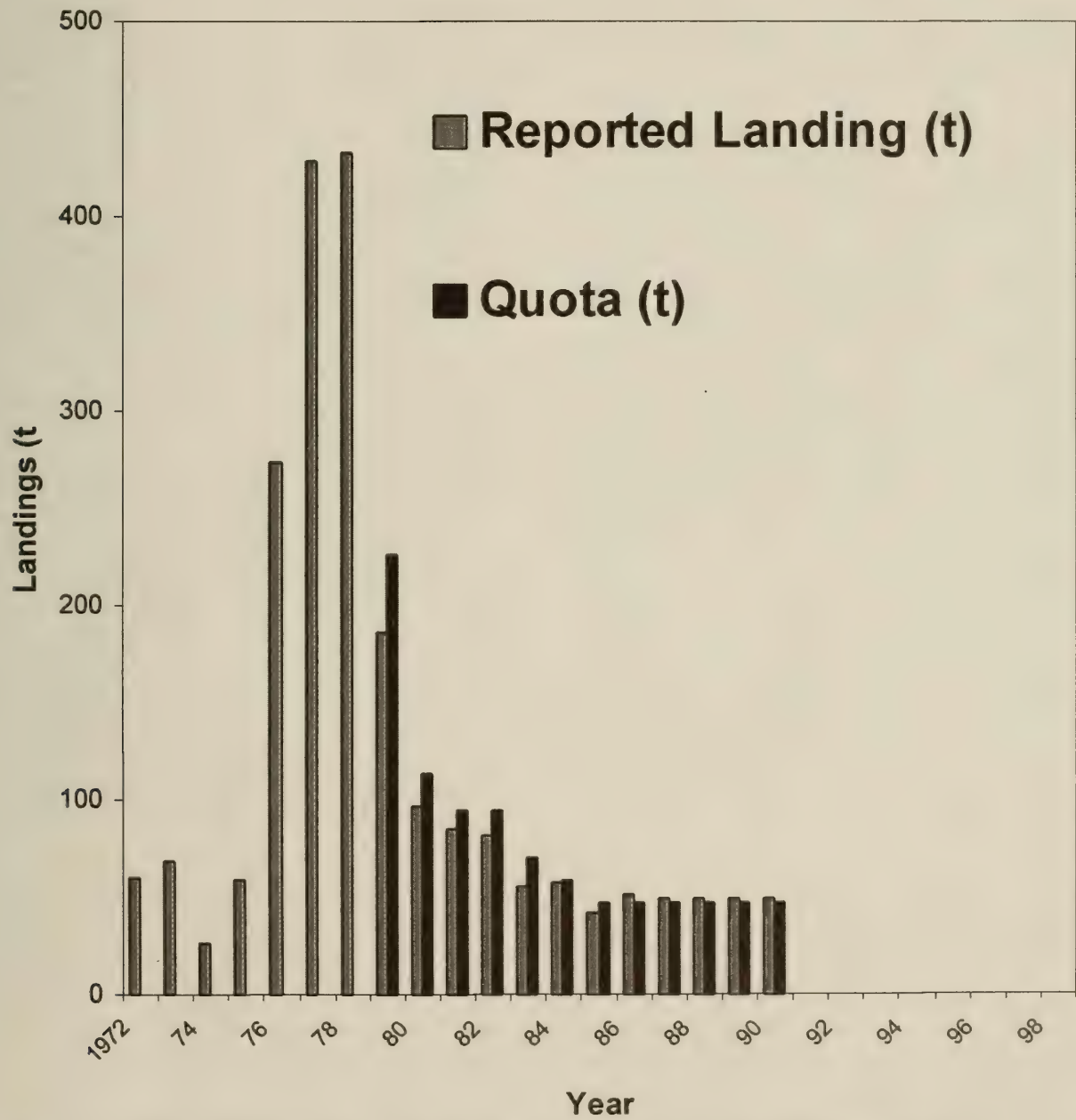


FIGURE 2. Reported Northern Abalone landings and quotas between 1972–1998 in British Columbia.

TABLE 1. Surveys of abalone abundance by region in northern British Columbia.

Year	Central Coast	Queen Charlotte Islands	Reference
1978		x	Breen and Adkins 1979
1979	x		Breen and Adkins 1981
1983	x		Boutillier et al. 1984
1984		x	Boutillier et al. 1985
1985	x		Farlinger and Bates 1986
1987		x	Carolsfeld et al. 1988
1989	x		Farlinger et al. 1991
1990		x	Thomas et al. 1992
1993	x		Thomas and Campbell 1996
1994		x	Winther et al. 1995
1995–96	x		Cripps and Campbell 1998
1997	x		Campbell et al. 1998

1980 was only ~450 t (Breen 1986). Annual production was initially assumed to be substantial because of the large initial biomass, but data from the mid-1980s indicated that annual recruitment was occurring at less than predicted levels (Breen 1980).

Concern about the apparent continuing decline in abalone abundance was regularly expressed in scientific advice to resource managers. The concern was never that abalone as a species would go extinct, but rather that local, accessible populations might either be extirpated or become so small that abalone would be difficult to find. At the least, abundance might become so low that abalone fisheries of any type could not be rationalised. This concern was reflected by reductions in annual quotas in the early 1980s, but logistic difficulties in sampling this widely and contagiously distributed species made the collection of comprehensive fisheries-independent abundance data difficult. In addition, biologists studying the species were not sure if the observed low recruitment at that time (Tables 2, 3) was part of a natural cycle in abundance determined by natural causes, or if it was indicative of over-exploitation. Because limited time-series data made scientific analysis ambiguous, and because of strong lobbying by industry for continuation of at least a reduced fishery, resource managers were hesitant to close the fishery. Instead, they gradually reduced annual quotas through to 1985 to the minimum level that would support existing fishers (Adkins 2000).

Abalone are broadcast spawners, and Northern Abalone recruitment characteristics were initially assumed to be similar to that of other local molluscs, notably bivalves. However, abalone recruitment appears to be different, and it is now recognised that their biology must also be considered in attempting to understand why Northern Abalone recruitment was not as high as was initially expected. World-wide, many abalone species have declined significantly in abundance coincident with the establishment of intensive export fisheries. It is now recognised that as a group abalone seem relatively vulnerable to over-exploitation (Tegner et al. 1996), and that particular attention must be given to monitoring and controlling their harvest (Tegner and Butler 1985; Prince et al. 1987, 1988; McShane et al. 1988; McShane 1992, 1995a,b; Campbell 2000). Reasons for this are not well understood for most abalone species, but Prince et al. (1988) suggested why this might be so in *Haliotis rubra* in Australia. Somewhat unique among exploited marine invertebrates, abalone have a particularly short larval period, typically being less than 10 days. In the early 1980s, it had been generally assumed that free-swimming meroplanktonic larvae dispersed relatively widely (Fedorenko and Sprout 1982). However, after considering a simple experiment, Prince et al. (1987) suggested that *Haliotis rubra* recruitment from a specific population was limited to the immediate vicinity of conspecifics. They hypothesised that dispersal of larvae for this species

TABLE 2. Abalone densities (number m⁻²) from 25 comparable sites in the Central Coast resurveyed in 1983, 1985, 1989 and 1993 (from Thomas and Campbell 1996).

Cohort	Year				
	1983	1985	1989	1993	1997
Total abalone	1.43	1.57	0.56	0.53	0.53
Legal size (100+ mm)	0.22	0.34	0.11	0.09	0.09
Prerecruits (94–101 mm)	0.18	0.25	0.08	0.06	0.06
Recruits (102–107 mm)	0.10	0.14	0.03	0.03	0.03

TABLE 3. Abalone densities (number m^{-2}) from 28 comparable sites in the Queen Charlotte Islands resurveyed in 1984, 1987, 1990 and 1994 (from Winther et al. 1995).

Cohort	Year				
	1979	1984	1987	1990	1994
Total abalone	3.54	0.69	0.79	0.44	0.33
Legal size (100+ mm)	0.30	0.09	0.13	0.07	0.06
Prerecruits (92–99 mm)	0.27	0.08	0.07	0.04	0.03
Recruits (100–106 mm)	0.14	0.04	0.05	0.04	0.02

was generally limited to < 50 m. Prince et al. (1988) then conducted a more extensive study to further test this hypothesis and they concluded that larval dispersal for this species could be as small as 10 to 100 m and that limited dispersal was indeed the most likely explanation for their observations. Thus, widespread dispersal of meroplanktonic larvae for species where this has not been shown to occur should not always be assumed, particularly if nothing is known about larval behaviour under field conditions. Prince et al. (1988) noted that concentration of fishing within specific areas may have serious negative effects on abalone populations and could lead to recruitment overfishing.

We currently have no data about the dispersal characteristics of Northern Abalone larvae (Campbell 2000), but it seems appropriate to assume that this species also has limited larval dispersal. Abalone fishing in Canada involves divers finding concentrations of abalone, and then harvesting all they can find above the minimum legal size limit. As previously cryptic animals become accessible over time, a population may gradually be depleted of most of its spawning adults, particularly if the minimum legal size limit is not the most appropriate. Poaching, where size limits would be less likely considered, would only make the situation worse.

Specific details of the decline in abundance may also be important. While 50% of Northern Abalone were estimated to be mature at a 55-mm shell length, the importance of large mature female abalone in contributing to total population fecundity has probably been underestimated. For example, at an eastern Moresby Island study site in 1990, 20% of mature female abalone were above the legal size of 100 mm shell length, yet these large abalone were estimated to produce 50% of the total potential eggs released by that population (Campbell et al. 1992). The fishery targeted larger animals (Sloan and Breen 1988), which may have had a greater impact on population fecundity than realised in the early 1980s. There is no described stock-recruitment relationship for the species (Campbell 2000), but a precautionary approach (Richards and Maguire 1998) argues that management should maintain gamete production at a level that accommodates uncertainty.

Another major problem was illegal harvesting, or poaching (Farlinger and Thomas 1989; Farlinger

1990; Campbell 2000; Jubinville 2000). Coincident with a reduction in the legal quota for abalone, dive fisheries for both Geoduck (*Panopea abrupta*) and Red Sea Urchins (*Strongylocentrotus franciscanus*) were expanding. Expansion of sea urchin fishing was particularly important because urchins and abalone occur in the same habitat and depth range. Many commercial and recreational divers were thus encountering abalone on a regular basis. Reduced quotas for abalone increased their price per kilogram, making it increasingly attractive for poachers to harvest abalone illegally.

Subsequent to the summary documents of Sloan and Breen (1988) and Jamieson (1989), resurveys of harvested areas continued in northern British Columbia (Table 1), with either the south-east Queen Charlotte Islands or the Central Coast sampled in any year. In 1987, it looked like abalone recruitment in the Queen Charlotte Islands might be finally increasing (Table 3), but no similar pattern was observed in the 1989 survey of the Central Coast (Table 2). Conservation of the species was now considered to be a significant issue, but before the fishery was closed, it was decided to conduct one more survey in the Queen Charlotte Islands to determine if the recruitment pulse observed in 1987 was being sustained. Results of the 1990 survey (Table 3) indicated it was not, and so the Department of Fisheries and Oceans (DFO) took the then-unprecedented step of closing all abalone fishing, initially for five years (Farlinger 1990). However, subsequent surveys (Tables 2, 3) demonstrated no stock rebuilding (Campbell 2000), and so aboriginal, recreational and commercial fisheries remain closed indefinitely (Adkins 2000).

Abalone abundance in southern British Columbia was also reduced to a low level by overfishing in the early years of the fishery (Adkins 1996), with again little sign of population recovery to date. There remains a population of large, relatively old abalone in the immediate vicinity of William's Head Penitentiary near Victoria, British Columbia, as penitentiary guards discourage nearshore access to fishers and poachers in an effort to minimise opportunity for inmate escape (Wallace 1997).

Establishing recreational and commercial fishery closures does not mean that all abalone fishing

stopped. Illegal fishing is still considered to be substantial in British Columbia (Adkins 2000; Campbell 2000; Jubinville 2000). Undocumented and potentially unreliable sources suggested that the illegal fishery in 1990 at the time of the fishery closure may have been up to five times the size of the then-legal fishery (47.2 t). There is still an indication that the current illegal harvest is up to several times the pre-closure legal harvest, and enforcement of a closure by the DFO is proving difficult. DFO fishery officers try to enforce the law (Jubinville 2000), but abalone volumes landed at any one time are often small and hidden with other much larger volumes of other legally-landed species. There have been a few significant arrests and convictions involving thousands of abalone (Jubinville 2000). Other fishery issues, notably management of herring and salmon fishing during the spring, summer or fall when most abalone are likely poached, have been of higher priority for fishery officers and there has been relatively little allocation of resources to address effectively the illegal abalone harvest. Many Asian restaurants in Vancouver in particular have openly listed abalone on their menus, but the paper trail to identify their sources is time-consuming and difficult to follow because the species can be harvested elsewhere in the north-east Pacific. The problem is a little like the illegal drug trade - value and potential gain are now so high that with the relatively limited law enforcement resources available, all illegal fishing cannot realistically be stopped or curtailed (Jamieson 2000). Existing marine protected areas (Jamieson and Lessard 2000) in British Columbia appear to offer little additional protection for Northern Abalone, as enforcement of fishing regulations at these locations is generally no better than the existing enforcement of fishery restrictions anywhere on the entire coast.

Washington State has never had commercial fishing for Northern Abalone, and Alaska's commercial fishery was closed in 1995 (Woodby et al. 2000). The recreational fishery for abalone in Washington was closed in 1994, also because of conservation concern (B. Sizemore, Washington Department of Fish and Game, Olympia, Washington, personal communication). An Alaskan sport fishery for abalone (minimum legal size = 89 mm (3.5 in)) currently exists, but abalone cannot be fished with SCUBA gear, which means that harvests are only through snorkelling or handpicking in the intertidal zone. The magnitude of abalone poaching in Alaska and Washington State is undocumented.

In recent years, methodology used to survey abalone stocks in British Columbia has been evaluated (Campbell 1996) and criteria proposed that if met, could justify reopening Northern Abalone fisheries in British Columbia (Campbell 1997). A common method has been used in all surveys to date to provide a series of comparable data, but concern exists

that this method is not sufficiently precise to detect small changes in population density (Farlinger and Campbell 1992). Campbell (1996) described the advantages of modifying the present survey technique, but these changes have been only minimally implemented, in part because major a methodology change would mean starting a new data series and result in a short-term inability to compare data. Criteria for reopening the fishery can not be fully defined at the present because of a lack of data on the frequency and patch size of adult Northern Abalone concentrations that would be required to maintain sufficient recruitment for a healthy population. As mentioned above, studies on other abalone species indicate that larval dispersal is not as extensive as with other mollusc broadcast spawners. This makes the spatial distribution of abalone patches important. Also, dilution of gamete concentration through reduced adult spawner densities can reduce fertilisation success (Clavier 1992; McShane 1995a, 1995b; Shepherd and Partington 1995), making the number of spawning abalone and their localised spatial distribution in any concentration important.

The range of Sea Otters in British Columbia is expanding and their abundance is increasing (average rate of 18.6% per year on the west coast of Vancouver Island; Watson et al. 1997; Watson 2000), following their reestablishment at a few isolated locations in the period 1969–1972. The population has increased from 89 animals introduced between 1969 to 1972 to over 2500 in 1998 in two disjunct populations (Watson 2000): about 2000 along northwest Vancouver Island and about 500 in the central portion of the British Columbian coast in Queen Charlotte Sound. Ultimately, unless extensively harvested in certain localities, Sea Otters can be expected to regain all of their original range, which includes most, if not all, habitats presently occupied by Northern Abalone. Abalone can coexist with Sea Otters, but at a relatively low density as cryptic individuals (Watson and Smith 1996; Watson 2000). Abalone fisheries and unharvested Sea Otters are unlikely to coexist (Watson 2000) because humans with SCUBA equipment and Sea Otters are both very efficient predators and competitors for abalone.

Protection

Haliotis kamtschatkana is still afforded no special treatment in law, although the provisions of the Fisheries Act provide some measure of control to legal aboriginal, recreational and commercial exploitation. Because of significant reductions in regional abundance, legal fisheries for abalone have been closed by Fisheries regulation in Canada since 1990. However, because demand for abalone worldwide and particularly in Canada is high, the closure simply resulted in a dramatic increase in price per pound (estimated to now be about \$100 per kg

(Jubenville 2000)), with the result that poaching of abalone continues to be a serious problem. Campbell (1997) suggested that obtaining a COSEWIC classification of either "Endangered" (species facing imminent extirpation or extinction) or "Threatened" (a species likely to become endangered if limiting factors are not reversed) would help to emphasise the serious poaching problem with this species and help to justify the resources required for conservation of this species.

Management Options

Given the current high value of abalone, other higher fishing resource management priorities, and the logistic difficulties of restricting abalone poaching, it seems unlikely that abalone poaching can be significantly reduced below the current level unless it is made illegal to possess abalone in Canada, including imports from other countries. Even this action may not stop the illegal export of poached abalone, but it would curtail local demand for the product. Establishing marine protected areas to further protect abalone is likely to only work if people in local communities assist in trying to rebuild local abalone stocks by reporting, and hopefully preventing, local fishing infractions (Jamieson 2000). With fishing now illegal but poaching still occurring, reliance on enforcement officers alone to prevent abalone poaching can not guarantee the long-term protection of specific populations.

Abalone can be cultured, and a number of groups, particularly First Nations, have proposed the establishment of abalone hatcheries to enhance local abalone populations and thereby allow the reestablishment of local abalone fisheries. While probably technically feasible, the economics may not be viable, and it may be more profitable to hold cultured abalone in closed pens until they reach a marketable size. Even in the absence of Sea Otters, the mortality of cultured Northern Abalone released as juveniles for grow-out in the wild and later harvest may be high, from natural predators when small and from poachers when large. It may also be difficult to fully separate wild from "cultured-and-released" individuals at the marketplace, meaning that to protect wholly "wild" stocks, released animals would not likely be harvestable from the wild until they reached the minimum legal size for wild abalone (100 mm in 1990). Continuous holding of cultured abalone in tanks might mean that smaller abalone could be marketed, but poachers might then increasingly target smaller wild abalone if practical techniques to separate wild from cultured abalone are not available. Any abalone culture is thus likely to open the door to further, or at least continued, abalone poaching.

From a sustainable population perspective, determining an historical population size baseline for Northern Abalone may be a major COSEWIC issue.

Humans have impacted abalone abundance twice — initially by eliminating a major natural predator, which is assumed to have increased adult abundance, and then by overharvesting, which decreased adult abundance and perhaps returned it to more historic levels. Over the extreme long term (i.e., centuries), Northern Abalone abundance over much of its range may have been relatively low (at least compared to the 1950s and 1960s) if predation of abalone by Sea Otters was high. From a COSEWIC status perspective, humans seem to have had a mixed impact on Northern Abalone compared to that of other severely depleted species. However, we have no scientific data on Northern Abalone abundance in the long ago past. All we know is that while past predation of abalone may have been high, recent removals by fishers have also been high, and with both these combined sources of mortality likely to continue, abalone seem unlikely to occur in abundance anywhere on the coast in the near future. The ranges of Sea Otters and Northern Abalone may never have totally overlapped on a microhabitat scale, but the ranges of fishers and Northern Abalone almost certainly do. Sea Otters also prey on many other species, and do not target abalone in the same manner than fishers do.

Given the criterion of relative change in abundance used to determine status, the speculated historical abundance of abalone may be an issue that needs debate. The issue of abalone poaching can be considered of immediate ecosystem importance because even in the long run poaching removes potential food items from Sea Otters as they expand their range, thereby affecting the possible rate of Sea Otter range expansion. Alternatively, poaching can be considered as simply replacing one efficient predator (Sea Otters) with another (humans), which makes little difference to an abalone that is killed.

Evaluation

From a COSEWIC perspective, I suggest that only recent decadal changes in abundance be considered in assigning status, as who knows what the past really was and what the future will bring. For a variety of reasons, Sea Otters may never, or at least not in the foreseeable future, reoccupy their historical range, and so Northern Abalone abundance should be considered on the basis of its current potential level and how it is being impacted by humans. The effects of illegal fishing are an immediate serious problem, and all factors influencing abalone abundance need consideration.

Given the above, I suggested that Northern Abalone be listed as "Threatened". Northern Abalone abundance over most of its range in British Columbia has been greatly reduced by fishing, and is probably less than 5% of the level that occurred immediately prior to the commencement of the industrial fishery.

There is no evidence that populations are increasing in abundance, and population size may still be decreasing. Over the past decade, information about the Northern Abalone fishery closure has been made available to the public, but there may still be opportunities to better educate people on the need to protect abalone.

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Rare and Endangered Fishes and Marine Mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports XIV

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Ten status reports representing the 1999 fish and marine mammal status assignments have been prepared for publication as well as two additional reports, one each from 1998 and 2000. Committee (COSEWIC) and Subcommittee (Fish and Marine Mammals) activities, including the implications of proposed legislation for the protection of wildlife species at risk in Canada, are briefly discussed.

Dix rapports de statut relativement aux poissons et aux mammifères marins auxquelles ont été attribués un statut en 1998 ont été préparés pour publication; il y a aussi deux rapports additionnels de 1998 et 2000 respectivement. Les activités du Comité (CSEMDC) et du sous-comité (des poissons et des mammifères marins), sont brièvement discutées, même que les implications de la loi proposée concernant la protection des espèces sauvages en péril au Canada.

Key Words: Rare and Endangered species, fish, marine mammals, COSEWIC.

As indicated in previous submissions (Campbell 1984 through 2001), the intent of the Subcommittee on Fish and Marine Mammals has been to publish (as funding permits) the status reports (on those species of fish and marine mammals) which the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has reviewed, approved and used as a basis of assigning status to species in jeopardy in Canada. The group of reports presented herein represent the seven fishes and the three marine mammals considered by COSEWIC and assigned status in 1999 (*see* Table1; COSEWIC 1999). An additional report on the Redfin Pickerel (*Esox americanus americanus*) is included. This report is from the 1998 status assignments, but not included in the publication of that set (*see* Campbell 2001). This series also contains one update from the group considered in 2000 at the request of the authors. Summaries of these (and any and all other status reports) are available from the COSEWIC Secretariat (Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3).

Progress

COSEWIC has undertaken to make available to all Canadians supporting information on each species classified (*see* Cook and Muir 1984). The Fish and Marine Mammal Subcommittee has been able to use this journal as one step in achieving the goal. A series of reports have appeared in various volumes and numbers from 1984 through 1998 [*see* *Canadian Field-Naturalist* 98(1): 63–133; 99(3): 404–450; 101(2): 165–309; 102(1): 81–176 and 102(2): 270–398; 103(2): 147–220; 104(1): 1–145;

105(2): 151–250; 106(1): 1–72; 110(3): 462–532; 111(2): 249–307; 112(1): 94–157; 115(1): 115–167].

As of April 1999, COSEWIC has reviewed the status of 109 fish species and 61 marine mammals (*see* Table1; COSEWIC 1999). Of the 170 species (or discrete populations) investigated 11 are indeterminate (seven fish, four marine mammals), 65 (30 fish, 35 marine mammals) have been found not to require status designation and another 50 (42 fish, eight marine mammals) have been designated as vulnerable leaving 33 species (22 fish, 11 marine mammals) of immediate concern (threatened and endangered), and 11 species (eight fish, three marine mammals) extinct or extirpated.

As of April 1999 there are 27 status reports on fish species (includes 15 updates), and 6 on marine mammal species (three updates) under review or in preparation (Table 2). Several of these were presented to the Committee for status assignment in 2000 and 2001.

As well, some 73 additional species of fish (plus 23 to be updated) and one marine mammal (plus four to be updated) are on the list for possible future consideration (Table 3). A few may be found to not require status designation, but the process serves to bring together the information necessary to make the appropriate determination and satisfy the need to fill those knowledge gaps. Although some of these may be of no immediate concern, the Subcommittee will, as opportunity allows, attempt to document the status of these species to determine their status in Canada.

In addition to soliciting further status reports on species of concern, the Subcommittee continues to

Table 1. Fish and Marine Mammal Species with Assigned COSEWIC Status to April 1999.

Species	Scientific Name	Status	Date Assigned
FISH			
Lake Sturgeon	<i>Acipenser fulvescens</i>	Not At Risk	April 1986
Bloater	<i>Coregonus hoyi</i>	Not At Risk	April 1988
Blueback Herring	<i>Alosa aestivalis</i>	Not At Risk	April 1980
Cutlips Minnow	<i>Exoglossum maxillingua</i>	Not At Risk	April 1994
Eastern Silvery Minnow	<i>Hybognathus nuchalis regius</i>	Not At Risk	April 1997
Striped Shiner	<i>Luxilus chyrsocephalus</i>	Not At Risk	April 1993
Redfin Shiner	<i>Lythrurus umbratilis</i>	Not At Risk	April 1988
Hornyhead Chub	<i>Nocomis biguttatus</i>	Not At Risk	April 1988
River Chub	<i>Nocomis micropogon</i>	Not At Risk	April 1988
Ghost Shiner	<i>Notropis buchanaani</i>	Not At Risk	April 1993
Blackchin Shiner	<i>Notropis heterodon</i>	Not At Risk	April 1994
Weed Shiner	<i>Notropis texanus</i>	Not At Risk	April 1999
Bluntnose Minnow	<i>Pimephales notatus</i>	Not At Risk	April 1998
Leopard Dace	<i>Rhinichthys falcatus</i>	Not At Risk	April 1990
Central Stoneroller	<i>Campostoma anomalum</i>	Not At Risk	April 1998
Mountain Sucker	<i>Catostomus platyrhynchus</i>	Not At Risk	April 1991
Golden Redhorse	<i>Moxostoma erythrurum</i>	Not At Risk	April 1989
Redfin Pickerel	<i>Esox americanus americanus</i>	Not At Risk	April 1998
Chain Pickerel	<i>Esox niger</i>	Not At Risk	April 1997
Least Darter	<i>Etheostoma microperca</i>	Not At Risk	April 1989
Tesselated Darter	<i>Etheostoma olmstedii</i>	Not At Risk	April 1993
River Darter	<i>Percina shumardi</i>	Not At Risk	April 1989
Green Sunfish	<i>Lepomis cyanellus</i>	Not At Risk	April 1987
Longear Sunfish	<i>Lepomis megalotis</i>	Not At Risk	April 1987
Spoonhead Sculpin	<i>Cottus ricei</i>	Not At Risk	April 1989
Brook Silverside	<i>Labidesthes sicculus</i>	Not At Risk	April 1989
Y-Prickleback	<i>Allolumpenus hypochromus</i>	Not At Risk	April 1991
Darktail Lamprey	<i>Lethenteron alaskense</i>	Indeterminate	April 1990
Bering Cisco	<i>Coregonus laurettae</i>	Indeterminate	April 1990
Mira Whitefish	<i>Coregonus</i> sp.	Indeterminate	April 1999
Chiselmouth	<i>Acrocheilus alutaceus</i>	Indeterminate	April 1997
Flathead Catfish	<i>Pylodictis olivaris</i>	Indeterminate	April 1993
Spinynose Sculpin	<i>Asemichthys taylori</i>	Indeterminate	April 1997
Pixy Poacher	<i>Ocella impi</i>	Indeterminate	April 1991
Lake Lamprey	<i>Lampetra macrostoma</i>	Vulnerable	April 1998
Chestnut Lamprey	<i>Ichthyomyzon castaneus</i>	Vulnerable	April 1991
Northern Brook Lamprey	<i>Ichthyomyzon fossor</i>	Vulnerable	April 1991
Shortnose Sturgeon	<i>Acipenser brevirostrum</i>	Vulnerable	April 1980
Green Sturgeon	<i>Acipenser medirostris</i>	Vulnerable	April 1987
White Sturgeon	<i>Acipenser transmontanus</i>	Vulnerable	April 1990
Spotted Gar	<i>Lepisosteus oculatus</i>	Vulnerable	April 1994
Spring Cisco	<i>Coregonus</i> sp.	Vulnerable	April 1992
Squanga Whitefish	<i>Coregonus</i> sp.	Vulnerable	April 1988
Kiyi	<i>Coregonus kiyi</i>	Vulnerable	April 1987
Pacific Sardine	<i>Sardinops sagax</i>	Vulnerable	April 1987
Atlantic Cod	<i>Gadus morhua</i>	Vulnerable	April 1998
Redside Dace	<i>Clinostomus elongatus</i>	Vulnerable	April 1987
Western Silvery Minnow	<i>Hybognathus argyritis</i>	Vulnerable	April 1997
Silver Chub	<i>Macrhybopsis storeriana</i>	Vulnerable	April 1985
Pugnose Shiner	<i>Notropis anogenus</i>	Vulnerable	April 1985
Bridle Shiner	<i>Notropis bifrenatus</i>	Vulnerable	April 1999
Bigmouth Shiner	<i>Notropis dorsalis</i>	Vulnerable	April 1985
Silver Shiner	<i>Notropis photogenis</i>	Vulnerable	April 1987
Roseyface Shiner (Manitoba)	<i>Notropis rubellus</i>	Vulnerable	April 1994
Pugnose Minnow	<i>Opsopoeodus emiliae</i>	Vulnerable	April 1985
Speckled Dace	<i>Rhinichthys osculus</i>	Vulnerable	April 1980f
Umatilla Dace	<i>Rhinichthys umatilla</i>	Vulnerable	April 1988
Banded Killifish (Newfoundland)	<i>Fundulus diaphanus</i>	Vulnerable	April 1989
Blackstripe Topminnow	<i>Fundulus notatus</i>	Vulnerable	April 1985

continued

Table 1. *continued*

Species	Scientific Name	Status	Date Assigned
Lake Chubsucker	<i>Erimyzon sucetta</i>	Vulnerable	April 1994
Bigmouth Buffalo	<i>Ictiobus cyprinellus</i>	Vulnerable	April 1989
Black Buffalo	<i>Ictiobus niger</i>	Vulnerable	April 1989
Spotted Sucker	<i>Minytrema melanops</i>	Vulnerable	April 1994
River Redhorse	<i>Moxostoma carinatum</i>	Vulnerable	April 1987
Greenside Darter	<i>Etheostoma blennioides</i>	Vulnerable	April 1990
Brindled Madtom	<i>Noturus miurus</i>	Vulnerable	April 1985
Northern Madtom	<i>Noturus stigmosus</i>	Vulnerable	April 1998
Redbreast Sunfish	<i>Lepomis auritus</i>	Vulnerable	April 1989
Warmouth	<i>Lepomis gulosus</i>	Vulnerable	April 1994
Orangespotted Sunfish	<i>Lepomis humilis</i>	Vulnerable	April 1989
Cultus Pygmy Sculpin	<i>Cottus</i> sp.	Vulnerable	April 1997
Fourhorn Sculpin (Arctic Islands)	<i>Myoxocephalus quadricornis</i>	Vulnerable	April 1989
Giant Stickleback	<i>Gasterosteus</i> sp.	Vulnerable	April 1980
Unarmoured Stickleback	<i>Gasterosteus</i> sp.	Vulnerable	April 1983
Blackline Prickleback	<i>Acantholumpenus mackayi</i>	Vulnerable	April 1989
Bering Wolffish	<i>Anahichas orientalis</i>	Vulnerable	April 1989
Morrison Creek Lamprey	<i>Lampetra richardsoni marifuga</i>	Threatened	April 1999
Lake Simcoe Whitefish	<i>Coregonus clupeaformis</i> ssp.	Threatened	April 1987
Blackfin Cisco	<i>Coregonus nigripinnis</i>	Threatened	April 1988
Shortnose Cisco	<i>Coregonus reighardi</i>	Threatened	April 1987
Shortjaw Cisco	<i>Coregonus zenithicus</i>	Threatened	April 1987
Lake Utopia Dwarf Smelt	<i>Osmerus</i> sp.	Threatened	April 1998
Black Redhorse	<i>Moxostoma dusquesnei</i>	Threatened	April 1988
Copper Redhorse	<i>Moxostoma hubbsi</i>	Threatened	April 1987
Eastern Sand Darter	<i>Ammocrypta pellucida</i>	Threatened	April 1994
Channel Darter	<i>Percina copelandi</i>	Threatened	April 1993
Enos Lake Sticklebacks (Species Pair)	<i>Gasterosteus</i> spp.	Threatened	April 1988
Paxton Lake Sticklebacks (Species Pair)	<i>Gasterosteus</i> spp.	Threatened	April 1999
Vananda Creek Sticklebacks (Species Pair)	<i>Gasterosteus</i> spp.	Threatened	April 1999
Margined Madtom	<i>Noturus insignis</i>	Threatened	April 1989
Shorthead Sculpin	<i>Cottus confusus</i>	Threatened	November 1983
Deepwater Sculpin (Great Lakes)	<i>Myoxocephalus thompsoni</i>	Threatened	April 1987
Atlantic Whitefish	<i>Coregonus huntsmani</i>	Endangered	April 1983
Aurora Trout	<i>Salvelinus fontinalis timagamiensis</i>	Endangered	April 1987
Nooksack Dace	<i>Rhinichthys cataractae</i> ssp.	Endangered	April 1996
Salish Sucker	<i>Catostomus</i> sp.	Endangered	April 1986
Paddlefish	<i>Polyodon spathula</i>	Extirpated	April 1987
Gravel Chub	<i>Erimystax x-punctata</i>	Extirpated	April 1987
Longjaw Cisco	<i>Coregonus alpenae</i>	Extinct	April 1988
Deepwater Cisco	<i>Coregonus johannae</i>	Extinct	April 1988
Banff Longnose Dace	<i>Rhinichthys cataractae smithi</i>	Extinct	April 1987
Blue Walleye	<i>Stizostedion vitreum glaucum</i>	Extinct	April 1985
Hadley Lake Sticklebacks (Species Pair)	<i>Gasterosteus</i> sp.	Extinct	April 1999
MARINE MAMMALS			
Sea Otter	<i>Enhydra lutris</i>	Threatened	April 1996
Sea Mink	<i>Mustela macrodon</i>	Extinct	April 1985
Northern Fur Seal	<i>Callorhinus ursinus</i>	Not At Risk	April 1996
Hooded Seal	<i>Cystophora cristata</i>	Not At Risk	April 1986
Bearded Seal	<i>Erignathus barbatus</i>	Not At Risk	April 1994
Grey Seal	<i>Halichoerus grypus</i>	Not At Risk	April 1999
Northern Elephant Seal	<i>Mirounga angustirostris</i>	Not At Risk	April 1986
Harbour Seal (Lac des Loups Marins)	<i>Phoca vitulina mellonae</i>	Vulnerable	April 1996
Harbour Seal (Atlantic & Arctic)	<i>Phoca vitulina richardsi</i>	Not At Risk	April 1999
Harbour Seal (Pacific)	<i>Phoca vitulina concolor</i>	Indeterminate	April 1999
Steller Sea Lion	<i>Eumetopias jubatus</i>	Not At Risk	April 1987
California Sea Lion	<i>Zalophus californianus</i>	Not At Risk	April 1987
Atlantic Walrus	<i>Odobenus rosmarus rosmarus</i>		
– Eastern Arctic		Not At Risk	April 1987
– Northwest Atlantic		Extirpated	April 1987

continued

Table 1. *Concluded*

Species	Scientific Name	Status	Date Assigned
Baird's Beaked Whale	<i>Berardius bairdi</i>	Not At Risk	April 1992
Beluga	<i>Delphinapterus leucas</i>		
– Beaufort Sea		Not At Risk	April 1986
– Western and Southern Hudson Bay		Not At Risk	April 1993
– High Arctic		Vulnerable	April 1992
– Eastern Hudson Bay		Threatened	April 1988
– St. Lawrence River		Endangered	April 1997
– S.E. Baffin Island		Endangered	April 1990
– Ungava Bay		Endangered	April 1988
Striped Dolphin	<i>Stenella coeruleoalba</i>	Not At Risk	April 1993
Ringed Seal	<i>Phoca hispida</i>	Not At Risk	April 1989
Common Dolphin	<i>Delphinus delphis</i>	Not At Risk	April 1991
Grey Whale	<i>Eschrichtius robustus</i>		
– Northeast Pacific		Not At Risk	April 1987
– Northwest Atlantic		Extirpated	April 1987
Risso's Dolphin	<i>Grampus griseus</i>	Not At Risk	April 1990
Short-finned Pilot Whale	<i>Globicephala macrohynchus</i>	Not At Risk	April 1993
Long-finned Pilot Whale	<i>Globicephala malaena</i>	Not At Risk	April 1994
Northern Bottlenose Whale	<i>Hyperoodon ampullatus</i>		
– Northwest Atlantic		Not At Risk	April 1993
– Gully Population		Vulnerable	April 1996
Pygmy Sperm Whale	<i>Kogia breviceps</i>	Not At Risk	April 1994
Dwarf Sperm Whale	<i>Kogia simus</i>	Indeterminate	April 1997
Atlantic White-sided Dolphin	<i>Lagenorhynchus acutus</i>	Not At Risk	April 1991
White-beaked Dolphin	<i>Lagenorhynchus albirostris</i>	Not At Risk	April 1998
Pacific White-sided Dolphin	<i>Lagenorhynchus obliquidens</i>	Not At Risk	April 1990
Northern Right Whale Dolphin	<i>Lissodelphis borealis</i>	Not At Risk	April 1990
Hubbs' Beaked Whale	<i>Mesoplodon carlhubbsi</i>	Not At Risk	April 1989
Blainville's Beaked Whale	<i>Mesoplodon densirostris</i>	Not At Risk	April 1989
True's Beaked Whale	<i>Mesoplodon mirus</i>	Not At Risk	April 1989
Stejneger's Beaked Whale	<i>Mesoplodon stejnegeri</i>	Not At Risk	April 1989
Narwhal	<i>Monodon monoceros</i>	Not At Risk	April 1987
Dall's Porpoise	<i>Phocoenoides dalli</i>	Not At Risk	April 1989
False Killer Whale	<i>Pseudorca crassidens</i>	Not At Risk	April 1990
Killer Whale	<i>Orcinus orca</i>		
– North Atlantic and Arctic		Indeterminate	April 1999
– North Pacific Transients		Vulnerable	April 1999
– North Pacific Residents		Threatened	April 1999
Sperm Whale	<i>Physeter macrocephalus</i>	Not At Risk	April 1996
Bottlenose Dolphin	<i>Tursiops truncatus</i>	Not At Risk	April 1993
Cuvier's Beaked Whale	<i>Ziphius cavirostris</i>	Not At Risk	April 1990
Blue Whale	<i>Balaenoptera musculus</i>	Vulnerable	April 1983
Fin Whale	<i>Balaenoptera physalus</i>	Vulnerable	April 1987
Sowerby's Beaked Whale	<i>Mesoplodon bidens</i>	Vulnerable	April 1989
Harbour Porpoise	<i>Phocoena phonoeca</i>		
– Northwest Pacific		Indeterminate	April 1991
– Northwest Atlantic		Threatened	April 1991
Humpback Whale	<i>Megaptera novaeangliae</i>		
– Northwest Atlantic		Vulnerable	April 1985
– Northeast Pacific		Threatened	April 1985
Bowhead Whale	<i>Balaena mysticetus</i>	Endangered	April 1986
Right Whale	<i>Eubalaena glacialis</i>	Endangered	April 1990

obtain updates on the status of selected species as new information becomes available, or during the 10-year review process initiated in 1993 (Table 2) for those species which had not already received further examination following the initial assignment of status.

Future Direction

The introduction to Series XI referred to proposed federal legislation in regards to a Species At Risk Act (Campbell 1997), but the Bill was not passed prior to the dissolution of Parliament in June 1997 and thus became non-existent (Campbell 1998).

However, the federal, provincial and territorial Ministers responsible for wildlife in Canada, recognizing that species are not respective of arbitrary jurisdictional boundaries, and that cooperation is crucial to the conservation of species at risk, reached a National Accord for the Protection of Species at Risk in June of 1996. The Ministers agreed to form a national council [Canadian Endangered Species Conservation Council (CESCC)] to coordinate their activities (in relation to the conservation of species at risk in Canada); to recognize COSEWIC as a source of independent advice on the status of species at risk; and to establish complementary legislation and pro-

grams to provide for the conservation and protection of species at risk throughout Canada. Such legislation and programs will, among other things: provide legal designation and protection for threatened and endangered species and their habitat; provide for the development and implementation of recovery plans; ensure multi-jurisdictional cooperation for the conservation of species that cross borders; ensure that species at risk are a part of the environmental assessment processes; monitor, assess and report on the status of wild species; and provide effective enforcement.

The Ministers went on to develop “A National

TABLE 2. Fish and Marine Mammal Species for which Status Reports are in preparation, or under review — to April 1999.

Species	Scientific Name	Proposed Status	
FISH			
Updated Reports		Current Status	
Chestnut Lamprey	<i>Ichthyomyzon castaneus</i>	Vulnerable	1991
Lake Sturgeon	<i>Acipenser fulvescens</i>	Not At Risk	1986
Aurora Trout	<i>Salvelinus fontinalis timagamiensis</i>	Endangered	1987
Shortjaw Cisco	<i>Coregonus zenithicus</i>	Threatened	1987
Silver Shiner	<i>Notropis photogenis</i>	Vulnerable	1987
Silver Chub	<i>Macrhybopsis storeriana</i>	Vulnerable	1985
Pugnose Shiner	<i>Notropis anogenus</i>	Vulnerable	1985
Bigmouth Shiner	<i>Notropis dorsalis</i>	Vulnerable	1985
Pugnose Minnow	<i>Opsopoeodus emiliae</i>	Vulnerable	1985
Redside Dace	<i>Clinostomus elongatus</i>	Vulnerable	1987
Speckled Dace	<i>Rhinichthys osculus</i>	Vulnerable	1980
Blackstripe Topminnow	<i>Fundulus notatus</i>	Vulnerable	1985
Brindled Madtom	<i>Noturus miurus</i>	Vulnerable	1985
Enos Lake Stickleback	<i>Gasterosteus</i> sp.	Threatened	1988
Pacific Sardine	<i>Sardinops sagax</i>	Vulnerable	1987
New Reports (Species Not Previously Considered)		Proposed Status	
Atlantic Sturgeon	<i>Acipenser oxyrhynchus</i>	Vulnerable	
Arctic Char	<i>Salvelinus alpinus</i>	?	
Round Whitefish	<i>Prosopium cylindraceum</i>	Vulnerable	
Lake Herring	<i>Coregonus artedii</i>	Great Lakes and BC population — may be Threatened	
Lake Whitefish	<i>Coregonus clupeaformis</i>	Populations of lakes Erie and Ontario may be Threatened	
Grass Pickerel	<i>Esox americanus vermiculatus</i>	Vulnerable	
Pearl Dace	<i>Margariscus margarita</i>	Vulnerable — BC, NT, NS	
Jasper Longnose Sucker	<i>Castostomus castostomus lacustris</i>	Vulnerable	
Greater Redhorse	<i>Moxostoma valenciennesi</i>	Vulnerable	
Mottled Sculpin	<i>Cottus bairdi</i>	Vulnerable — BC, Alberta	
Shorthead Sculpin	<i>Cottus confusus</i>	Threatened	
Bluefin Tuna	<i>Thunnus thynnus</i>	?	
MARINE MAMMALS			
Updated Reports		Current Status	
Bowhead Whale	<i>Balaena mysticetus</i>	Endangered	1986
Blue Whale	<i>Balaenoptera musculus</i>	Vulnerable	1983
Humpback Whale	<i>Megaptera novaeangliae</i>		
– Northwest Atlantic		Vulnerable	1985
– Northeast Pacific		Threatened	1985
New Reports (Species Not Previously Considered)		Proposed Status	
Minke Whale	<i>Balaenoptera acutorostrata</i>	?	
Sei Whale	<i>Balaenoptera borealis</i>	?	
Harbour Seal	<i>Phoca vitulina</i>	Lake Ontario — Extirpated	

TABLE 3. Fish and Marine Mammal Species of Possible Interest to COSEWIC — April 1999 (Not listed by Priority)

Species	Scientific Name	Possible Status	
SPECIES UPDATES			
Fish		Current Status	
Salish Sucker	Catostomus sp.	Endangered	1986
Lake Simcoe Whitefish	Coregonus clupeaformis	Threatened	1987
Blackfin Cisco	Coregonus nigripinnis	Threatened	1988
Black Redhorse	Moxostoma dusquesnei	Threatened	1988
Margined Madtom	Noturus insignis	Threatened	1989
Great Lakes Deepwater Sculpin	Myoxocephalus thompsoni	Threatened	1987
Shorthead Sculpin	Cottus confusus	Threatened	1984
Shortnose Sturgeon	Acipenser brevirostrum	Vulnerable	1980
Green Sturgeon	Acipenser medirostris	Vulnerable	1987
Squanga Whitefish	Coregonus sp.	Vulnerable	1987
Kiyi	Coregonus kiyi	Vulnerable	1988
Umatilla Dace	Rhinichthys umatilla	Vulnerable	1988
Bigmouth Buffalo	Ictiobus cyprinellus	Vulnerable	1989
Black Buffalo	Ictiobus niger	Vulnerable	1989
River Redhorse	Moxostoma carinatum	Vulnerable	1987
Redbreast Sunfish	Lepomis auritus	Vulnerable	1989
Orangespotted Sunfish	Lepomis humilis	Vulnerable	1989
Banded Killifish	Fundulus diaphanus	Vulnerable	1989
Fourhorn Sculpin (Arctic Islands)	Myoxocephalus quadricornis	Vulnerable	1989
Charlotte Stickleback	Gasterosteus sp.	Vulnerable	1983
Giant Stickleback	Gasterosteus sp.	Vulnerable	1980
Blackline Prickleback	Acantholumpenus mackayi	Vulnerable	1989
Bering Wolffish	Anarichus orientalis	Vulnerable	1989
Marine Mammals			
Beluga – Ungava Bay	Delphinapterus leucas	Endangered	1988
– Eastern Hudson Bay		Threatened	1988
Sowerby's Beaked Whale	Mesoplodon bidens	Vulnerable	1989
Fin Whale	Balaenoptera physalus	Vulnerable	1987
SPECIES YET TO BE CONSIDERED			
Fish		Possible Status	
Nass River Lamprey Species 1	Lampetra sp.	BC ?	
Nass River Lamprey Species 2	Lampetra sp.	BC ?	
Copper River Lamprey	Lampetra sp.	BC ?	
American Eel	Anquilla rostrata	Vulnerable	
American Shad	Alosa sapidissima	?	
Atlantic Herring	Clupea harengus	?	
Pacific Herring	Clupea pallasii	?	
Creek Chubsucker	Erimyzon oblongus	Extirpated – NB	
Brassy Minnow	Hybognathus hankinsoni	Vulnerable	
Pygmy Smelt	Osmerus spectrum	Vulnerable – QC	
Emerald Shiner	Notropis atherinoides	Vulnerable – BC	
Spottail Shiner	Notropis hudsonius	Vulnerable – BC	
Creek Chubsucker	Erimyzon oblongus	Threatened – ON	
Rainbow Darter	Etheostoma caeruleum	Vulnerable – QC	
Stonecat	Noturus flavus	Vulnerable – SK, QC	
Capelin	Mallotus villosus	?	
Broad Whitefish	Coregonus nasus	Vulnerable – BC	
Least Cisco	Coregonus sardinella	Vulnerable	
Giant Pygmy Whitefish	Prosopium sp.	Threatened – BC	
Pygmy Whitefish	Prosopium coulteri	Threatened – AB	
Ninespine Stickleback	Pungitius pungitius	Vulnerable – BC	
Pacific Salmonids	Oncorhynchus spp. (5)	?	
Atlantic Salmon	Salmo salar	?	
Euchalon	Thaleichthys pacificus	?	
Spiny Dogfish	Squalus acanthias	?	
Barndoor Skate	Raja laevis	Threatened	
Thorny Skate	Raja radiata	?	

continued

TABLE 3. continued

Species	Scientific Name	Possible Status
Smooth Skate	<i>Malacoraja senta</i>	?
Monkfish	<i>Lophius americanus</i>	?
Tomcod	<i>Microgadus tomcod</i>	Vulnerable – Quebec
Haddock	<i>Melanogrammus aeglefinus</i>	?
Silver Hake	<i>Merluccius bilinearis</i>	?
Pollock	<i>Pollachius virens</i>	?
Red Hake	<i>Urophycis chuss</i>	?
Rock Grenadier	<i>Coryphaenoides rupestris</i>	?
Pacific Ocean Perch	<i>Sebates alutus</i>	?
Aurora Rockfish	<i>Sebastes aurora</i>	?
Redbanded Rockfish	<i>Sebastes babcocki</i>	?
Silvergray Rockfish	<i>Sebastes brevispinis</i>	?
Copper Rockfish	<i>Sebastes caurinus</i>	?
Splitnose Rockfish	<i>Sebastes diploproa</i>	?
Widow Rockfish	<i>Sebastes entomelas</i>	?
Chilipepper	<i>Sebastes goodei</i>	?
Shortbelly Rockfish	<i>Sebastes jordani</i>	?
Quillback Rockfish	<i>Sebastes maliger</i>	?
Black Rockfish	<i>Sebastes melanops</i>	?
Vermillion Rockfish	<i>Sebastes miniatus</i>	?
Blue Rockfish	<i>Sebastes mystinus</i>	?
China Rockfish	<i>Sebastes nebulosus</i>	?
Golden Rockfish	<i>Sebates norvegicus</i>	?
Bocaccio	<i>Sebates paucispinis</i>	?
Canary Rockfish	<i>Sebates pinniger</i>	?
Yelloweye Rockfish	<i>Sebates ruberrimus</i>	?
Sripetail Rockfish	<i>Sebates saxicola</i>	?
Shortspine Thornyhead	<i>Sebastolobus alascanus</i>	?
Longspine Thornyhead	<i>Sebastolobus altivelis</i>	?
Lingcod	<i>Ophiodon elongatus</i>	?
Lumpfish	<i>Cyclopterus lumpus</i>	?
Wolffish	<i>Anarhichas lupus</i>	Vulnerable
Atlantic Mackerel	<i>Scomber scombrus</i>	?
Swordfish	<i>Xiphias gladius</i>	?
Summer Flounder	<i>Paralichthys dentatus</i>	?
Witch Flounder	<i>Glyptocephalus cynoglossus</i>	?
American Plaice	<i>Hippoglossoides platessoides</i>	?
Atlantic Halibut	<i>Hippoglossus hippoglossus</i>	?
Pacific Halibut	<i>Hippoglossus steolepis</i>	?
Yellowtail Flounder	<i>Limanda ferrugineus</i>	?
Winter Flounder	<i>Pseudopleuronectes americanus</i>	?
Greenland Halibut (Turbot)	<i>Reinhardtius hippoglossoides</i>	?
Marine Mammals		
Harp Seal	<i>Phoca groenlandica</i>	Not At Risk

Framework For The Conservation Of Species At Risk” to provide a coordinated national approach for the conservation of species at risk in Canada. CESSC is to be responsible for the National Framework , its implementation and the resolution of issues for the protection of species at risk in Canada. CESSC recognized COSEWIC as an independent committee of scientific experts mandated to assess the status of species which may be at risk nationally and provided terms of reference for COSEWIC. The organization will also provide the lead for the “Recovery of Species at Risk Nationally” (RENEW) organization which develops and implements recov-

ery plans for those species assessed by COSEWIC as threatened and endangered. The National Framework also includes provisions for the development of authority over wild species in each of the federal, provincial, and territorial jurisdictions which do not currently have such legislation. Endangered species legislation is under consideration by the federal parliament as well as by those provinces and territories which do not have such legislation.

Under the Accord and the National Framework, COSEWIC now reports to CESSC and is supported by a secretariat funded by Environment Canada. The secretariat is provided with a budget to facilitate

meetings, fund production and publication of status reports and communications. The basic structure and operation of COSEWIC remains much as it was (*see* Cook and Muir 1984) with some exceptions. The major changes are that members are now appointed by the (Federal) Minister of the Environment, as recommended by CESSC and the creation of a new subcommittee structure which will include the addition of an Aboriginal Traditional Knowledge Specialist Group.

There will now be eight subcommittees which are referred to as "Species Specialist Groups" (SSGs). An invertebrates subcommittee had been recognized in 1995 and that is why marine invertebrates no longer (since 1996) appeared as part of the fish and marine mammals reports. To-date the invertebrates SSG has only been mandated to examine lepidoptera and molluscs. The fish and marine mammal subcommittee is to be split into three SSGs, freshwater fishes, marine fishes and marine mammals. The four remaining specialists groups are the existing groups representing birds, "terrestrial" (i.e., non-marine) mammals, plants, and amphibians and reptiles.

COSEWIC is also in the process of adopting quantitative scientific assessment criteria based on the IUCN Red List Criteria (IUCN 1994). This will permit a process based on science and traditional or local knowledge to assess species at risk according to the probable risk of extinction. Future status assignments will be made using these criteria.

Concluding Remarks

The 12 reports included in the following series are based on reports on the status of the respective species in Canada. Status was assigned by consensus of the COSEWIC Committee based on the originals. Here they are published under the name(s) of the original author(s). The present reports have undergone minor editing to provide some degree of consistency in format and presentation.

As indicated above, COSEWIC is in a state of transition and has undergone some change in its structure and operation to pave the way for its taking on a legal basis under federal endangered species legislation. COSEWIC will maintain its independence and continue to provide assessments of status of species considered to be at risk in Canada based on the best scientific, traditional and local knowledge available. It is still mandated to make that information available to the public; however, at this time the possible continuation of this series in some form is uncertain. The publication of all reports, from all SSGs, in some format is under consideration. However, copies of all original reports are available from the COSEWIC Secretariat (c/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3) or the COSEWIC web site at <http://www.cosewic.gc.ca>.

The author has remained as co-chair of the freshwater fishes group and, if circumstances permit, would like to continue presenting the reports from that group and to provide updated information on COSEWIC and its operations and the progress of endangered species legislation in this forum.

Acknowledgments

The members of COSEWIC and the Fish and Marine Mammal Subcommittee would like to extend their thanks to the various authors who have so generously contributed their time and talents in support of COSEWIC. The Committee also wishes to acknowledge the members of the Subcommittee for their unstinting efforts in reviewing the reports and their helpful comments.

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Status of the Morrison Creek Western Brook Lamprey, *Lampetra richardsoni*, in Canada*

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Beamish, R. J., J. H. Youson, and L. A. Chapman. 2001. Status of the Morrison Creek Western Brook Lamprey, *Lampetra richardsoni*, in Canada. *Canadian Field-Naturalist* 115(4): 573–578.

The Morrison Creek Western Brook Lamprey, is a distinct and rare population of the widely distributed Western Brook Lamprey, *Lampetra richardsoni*, and it is endemic to a small creek on Vancouver Island, Canada. This special population produces both non-parasitic and potentially parasitic adult life history types, representing a unique type of polymorphism in lampreys. The Morrison Creek population demonstrates that a linkage between parasitic and non-parasitic lampreys exists and provides an opportunity to study lamprey speciation and evolution. However, this rare population is at risk because its habitat is currently facing substantial development pressures. The Morrison Creek *Lampetra richardsoni* population should be protected because of its important implications for our understanding of lamprey taxonomy and evolution, and because the potentially parasitic variety needs further study as it represents a life history that is difficult to classify with our existing knowledge.

La lamproie du ruisseau Morrison, *Lampetra richardsoni*, est endémique dans un petit cours d'eau de l'île de Vancouver, Canada; elle représente une forme distincte et rare de la lamproie de l'ouest, *Lampetra richardsoni*, qui, elle, jouit d'une grande distribution. Le ruisseau abrite les deux formes de *L. richardsoni* et celles-ci forment une population unique de lamproies qui produit des types biologiques adultes à la fois parasitiques et non parasitiques. Cette population polymorphe est un phénomène unique en son genre chez la lamproie dont l'ascendance remonte à au moins 350 millions d'années. Ce qui se passe dans le ruisseau Morrison revêt donc une grande pertinence pour ce qui est de la compréhension de l'évolution des premiers vertébrés. Toutefois, cette population rarissime est en danger car son habitat subit actuellement d'importantes pressions d'aménagement. Il est impératif que nous préservions le complexe des deux formes de la lamproie du ruisseau Morrison puisqu'il présente des implications importantes pour la compréhension de la taxonomie et de l'évolution de la lamproie et que la variété est un cas qu'il est difficile de classer dans l'état actuel des connaissances.

Key Words: Morrison Creek Western Brook Lamprey, lamproie du ruisseau Morrison, *Lampetra richardsoni*, polymorphic lampreys, parasitic lampreys, British Columbia, rare and endangered species, Petromyzontiformes.

Lampreys (Petromyzonidae) are a successful group of vertebrates that have survived for close to 350 million years and have had a conservative evolution (Forey and Janvier 1994). The reason for their evolutionary success is not known but may be attributed to their ability to change among the three adult life history types; anadromous and parasitic, nonanadromous and parasitic, and, nonanadromous and non-parasitic (Beamish 1987a). Direct evidence for this possibility comes from a rare population of *Lampetra richardsoni* that is presently known only from Vancouver Island, Canada. This population produces a potentially parasitic and a non-parasitic adult life history type each year, both of which are nonanadromous. The parasitic form is an undescribed variety of *Lampetra richardsoni* which we are tentatively calling the Morrison Creek variety. It should be noted that the variety has not been given

official taxonomic status, despite its distinctive life history and morphology relative to *Lampetra richardsoni*. The variety is parasitic in the laboratory and the taxonomy of lampreys uses adult life history type as a species specific character (Zanandrea 1959; Vladykov and Kott 1979; Potter 1980). Therefore, in a sense, this population produces two species according to conventional lamprey taxonomy. However, although the Morrison Creek variety could be considered a new species on the basis of morphology and life history type, the genetic similarity which exists between the two forms indicates that the variety is probably not a species but rather a unique morph of a single population (Beamish and Withler 1986).

It is thought that the Morrison Creek variety represents an intermediate step in the evolution of *Lampetra richardsoni* from an anadromous parasitic ancestor (Beamish 1985; Beamish and Withler 1986; Youson and Beamish 1991). The parasitic morph offers a rare opportunity to study the product of an evolutionary transition and to improve our understanding of lamprey taxonomy and evolution. For

*Reviewed and approved by COSEWIC April 1999, status assigned — Threatened

this reason, it is imperative that the Morrison Creek *Lampetra richardsoni* population is preserved and protected. We term this population a "variety" of *Lampetra richardsoni*, as variety *marifuga* which relates to the inability of this lamprey to survive in the ocean.

Distribution

The known distribution is extremely restricted, for this polymorphic population of *Lampetra richardsoni* has only been found in the Morrison Creek watershed, located on Vancouver Island, British Columbia, Canada (Figures 1 and 2). Morrison Creek is a small freshwater stream which originates from a series of springs (Beamish 1985). Stream channels in the higher gradient headwaters are typically 1–2 m wide and about 3–4 m in width at the lower reaches (Lough 1995a*,b*; Beamish 1985). Morrison Creek runs for approximately 35 kilometers until its confluence with the Puntledge River system, a few kilometers upstream of the ocean (Beamish 1985). Small numbers of the anadromous *Lampetra tridentata* have also been found in Morrison Creek (Beamish and Withler 1986).

Protection

There are currently no protection provisions for the Morrison Creek Western Brook Lamprey. However, due to the problems of declining wild Coho stocks in the Strait of Georgia, there has been an increased effort to protect and enhance fish habitat. A sensitive habitat atlas was created for the Comox-Strathcona region. It highlights the areas which contain sensitive aquatic and terrestrial habitat so that they are considered in any proposed land developments (Comox-Strathcona Sensitive Habitat Atlas 1995). Fish habitat in these areas are subject to fisheries protection regulations and guidelines; however, sometimes encroachment into sensitive habitats can not be avoided, and development plans must resort to mitigation and compensation strategies to replace the losses.

Population Numbers, Sizes and Trends

There are no reliable population estimates of *Lampetra richardsoni* in Morrison Creek. The number of spawning individuals (considered to be typical *Lampetra richardsoni*) caught in traps exceeded the number of the variety that have been captured (Beamish and Withler 1986). Furthermore, a sample of 18 metamorphosed lampreys collected in Morrison Creek produced two silver forms (the Morrison Creek variety) and the rest matured, spawned and died in the spring as would typical *Lampetra richardsoni* (Beamish 1985). Data suggest that the Morrison Creek variety was relatively stable during the initial studies which ran from 1978 to 1984 (Beamish 1985). However, it is possible that their numbers have declined in recent years

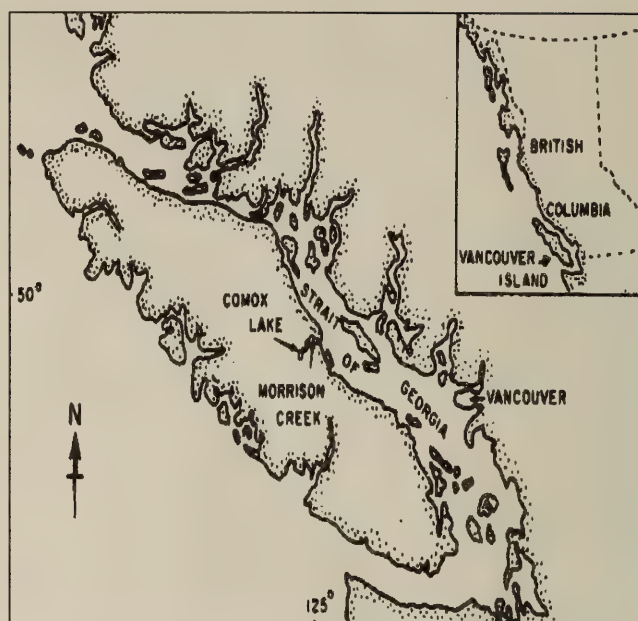


FIGURE 1. Location of Morrison Creek in British Columbia.

(Beamish unpublished data). The adults of the Morrison Creek variety range in size from 10 to 15 cm, and it is thought that their length increases after metamorphosis are small (Beamish 1985). The sex ratio of the variety appears to be about 80% male and the males contain gonads in an advanced stage of maturity at a time when females are immature or just beginning to mature (Beamish 1985). A difficulty has been the inability to catch adults after the summer (or rather to distinguish them from recently metamorphosed lampreys), thus the biology and fate

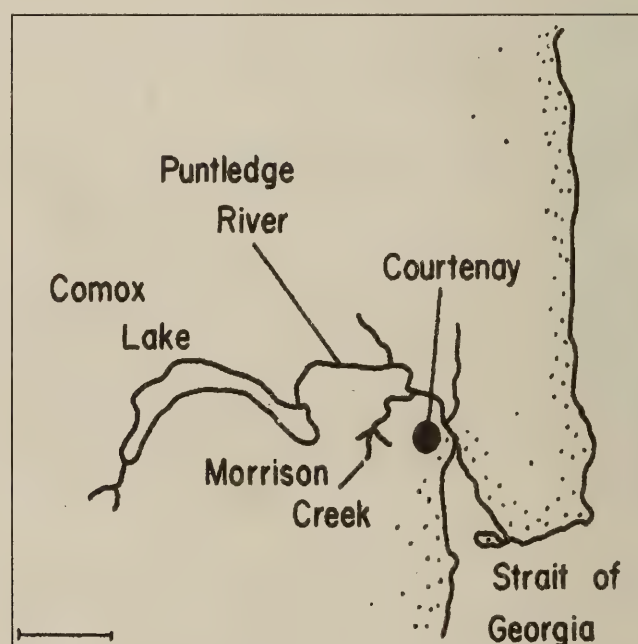


FIGURE 2. Location of Morrison Creek on Vancouver Island, the scale represents 4.2 km.

of the variety in Morrison Creek is unknown after the summer period (Beamish 1985).

Habitat

Habitat studies conducted on the upper watershed (Lough et al. 1995a*,b*; Knight and Blood 1997) indicate that the Morrison Creek area is characteristic of interlinking wetlands, with meadows, thick brush, beaver dams and open beaver ponds. The stream bed is dominated by compressed till with limited patches of small gravels and an abundance of stream debris which provide habitat diversity.

The creek is known for its Coho Salmon, *Oncorhynchus kisutch*, habitat and is a major contributor of Coho to the Puntledge River system (personal communication: Brian Allen, Department of Fisheries and Oceans, 148 Port Augusta, Comox, British Columbia). The specific habitat features required to support a polymorphic population of lamprey are not known.

The area surrounding Morrison Creek has, in the past, been disturbed by logging and mining activities which contribute to its complex hydrology (Knight and Blood 1997). Evidence of development pres-

ures are also seen in the mainstem of the creek where streambank degradation and the removal of in-stream debris has resulted in a loss of the pool/riffle complex (personal communication: Brian Allen, Department of Fisheries and Oceans, 148 Port Augusta, Comox, British Columbia).

General Biology

The biology of the Morrison Creek variety is not fully understood. Aside from an extended post-metamorphic period and the ability to be parasitic, its biology is very similar to that of typical *Lampetra richardsoni* (Beamish 1985). Typical *Lampetra richardsoni* from Morrison Creek remain in fresh water throughout their entire life cycle and begin to reproduce in May and June (Youson and Beamish 1991). The lamprey spawn only once and their eggs are deposited in river bed gravel. After hatching, the young quickly burrow into the soft bottom sediments where they spend an unknown time (possibly three to seven years) as filter feeding ammocoetes before metamorphosing into juveniles.

The population of *Lampetra richardsoni* in Morrison Creek begins metamorphosis in July or August and two adult forms appear in the spring of

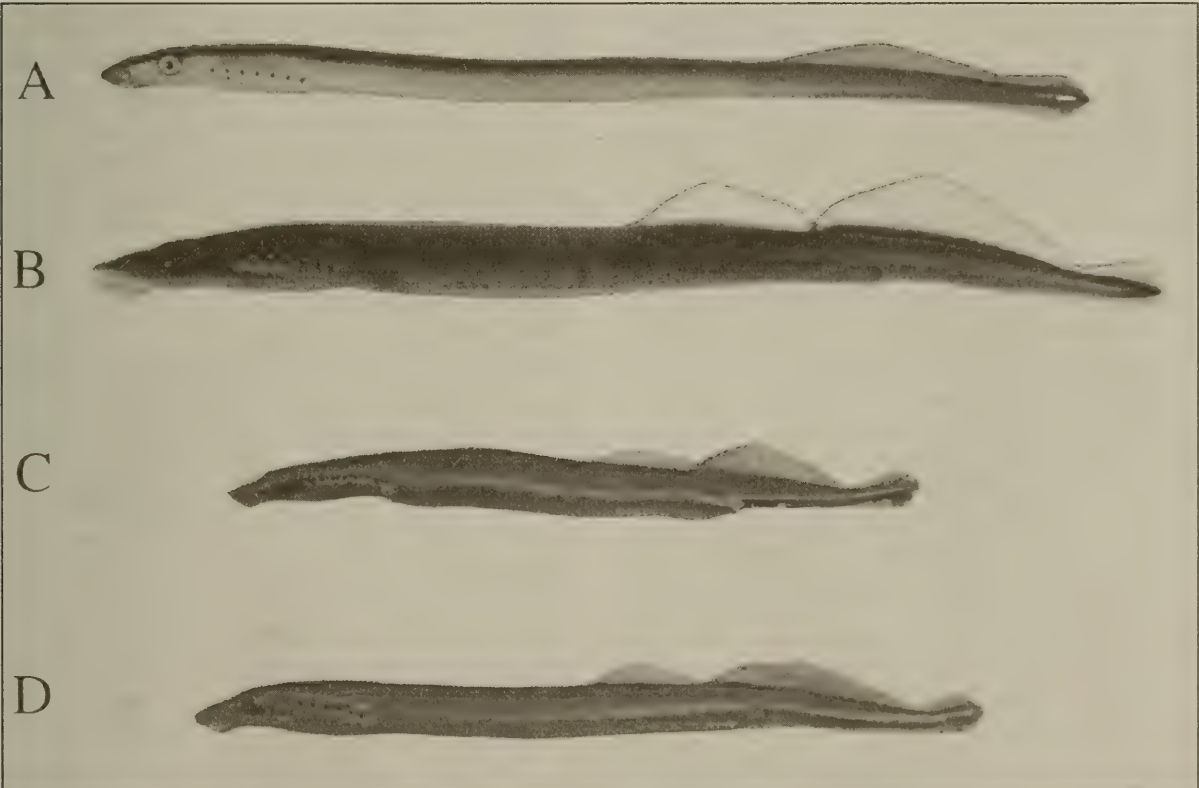


FIGURE 3. (A) Male of the Morrison Creek variety showing counter shading which develops in the spring following metamorphosis. The variety can live for one year longer than typical *Lampetra richardsoni* and is capable of feeding during this time under laboratory conditions. Total length is 13 cm. (B) Mature male of the Morrison Creek variety brought into the laboratory in June 1981 and regard to maturity in 1982. Total length is 18.5 cm. (C) Mature female and (D) mature male, typical *Lampetra richardsoni* from Morrison Creek, which spawn and die in the spring after metamorphosis. Total lengths are 12.5 cm and 11 cm respectively.

the following year: a spawning variety (Figure 3: C and D) with advanced signs of sexual maturation, typical of *Lampetra richardsoni*, and a parasitic variety (Figure 3: A and B), which is not completely mature and could delay another year before spawning (Beamish 1987a; Youson and Beamish 1991). No distinction has been made, however, between the two morphs of the population when they are ammocoetes.

Electrophoretic and morphological evidence (Beamish and Withler 1986; Beamish 1987b) have shown that the two forms of *Lampetra richardsoni* in Morrison Creek belong to a single population, thus forming a species complex. For instance, the non-parasitic morph is more genetically similar to the parasitic morph than it is to other *Lampetra richardsoni* populations from different streams. It is uncertain, however, whether the two morphs breed as independent lines. It is possible that the Morrison Creek variety does not survive to reproduce as its internal development at metamorphosis is not complete in all individuals (Youson and Beamish 1991). However, some individuals of the variety spawn successfully in the laboratory and produce viable eggs which hatch into larvae (Beamish 1985). Given that spawning was successful in the laboratory, it is also possible that the variety is reproducing in Morrison Creek. Identical allelic frequencies indicate that genetic exchange occurs between the two forms of *Lampetra richardsoni* in Morrison Creek (Beamish and Withler 1986).

The Morrison Creek variety is able to live for one year longer than typical *Lampetra richardsoni* as demonstrated in the laboratory (Beamish 1987a). Youson and Beamish (1991) found that the delayed maturation in males of the Morrison Creek variety allowed the retention of a functional digestive system which would provide an opportunity for feeding. The variety fed (on both live and dead fishes) and grew under laboratory conditions from July until mid-November and matured over the following spring (Beamish 1985). It is uncertain, however, whether the Morrison Creek variety feeds in the stream. Feeding may occur for only a short period and on food items other than live fishes (Beamish 1985). However, it is also possible that the variety does not feed in Morrison Creek and simply perishes before spawning.

The Morrison Creek variety, when not in spawning condition, is easily distinguished from typical *Lampetra richardsoni* by its silver color and counter shading, which develops in early spring, and by its prominent teeth (Beamish 1985). It was noted that the feeding variety maintained in the laboratory lost the silver color and became uniformly dark by the end of September (Beamish 1985).

The variety appears to be very similar to the closely related *Lampetra ayresi* but it differs in the number of cusps on some teeth, some aspects of its

morphology, in colour, and its inability to osmoregulate in salt water (Beamish 1985). It is possible that the Morrison Creek variety may be a natural hybrid of *Lampetra richardsoni* and *Lampetra ayresi*; however, *Lampetra ayresi* have not been found in the Morrison Creek or surrounding watersheds (Beamish 1985; Beamish and Withler 1986). Furthermore, no ammocoetes in Morrison Creek with pigmentation patterns typical of *Lampetra ayresi* crosses have been found (Beamish and Withler 1986).

Youson and Beamish (1991) compared the internal morphology of the two morphs and suggested that the intermediate parasitic lifestyle is due to a slower sexual maturation and, possibly, a slower and incomplete metamorphosis. The incomplete metamorphosis was particularly evident in females, which were far less developed than males, and this may account for the abnormal sex ratio (Youson and Beamish 1991). In addition, males of the parasitic variety were found to contain gonads in an advanced stage of maturity with no external signs of maturation and were capable of feeding (Beamish 1985; Beamish and Withler 1986; Beamish 1987a; Youson and Beamish 1991). This is the first documentation of a lamprey that is actively feeding in an advanced stage of maturity (Beamish and Withler 1986; Youson and Beamish 1991). The unusual biology of the Morrison Creek variety appears to represent a key phase of lamprey evolution. The inability to osmoregulate in salt water, the feeding habit in the laboratory, the precocious development in males, and the delayed organ development indicate that the variety is intermediate between a parasitic and non-parasitic form (Beamish 1985; Beamish and Withler 1986; Beamish 1987a; Youson and Beamish 1991).

Special Significance

The existence of a lamprey population in Canada that produces two distinct life history types has only been described from Morrison Creek. This rare population represents an important transition in the evolution of adult life history types in lampreys and may be the key to understanding why lampreys have been successful for over 350 million years.

Lampetra richardsoni is a close relative of the anadromous parasitic *Lampetra ayresi*, and they are considered to be a species pair (Zanandrea 1959; Vladykov and Kott 1979; Potter 1980). The evolutionary relationship between members of a species pair remains uncertain, although there is a widely accepted view that the non-parasitic form evolved from an anadromous parasitic form (Vladykov and Kott 1979; Potter 1980). The Morrison Creek variety is intermediate between the non-parasitic *Lampetra richardsoni* and the parasitic *Lampetra ayresi* in its biology and morphology (Beamish and Withler 1986). According to Zanandrea (1959, 1961), a freshwater feeding phase may be an inter-

mediate step in the evolution of freshwater non-parasitic lampreys from anadromous parasitic forms. The existence of the Morrison Creek variety provides evidence of this intermediate freshwater feeding phase.

Histological evidence indicates that the freshwater parasitic lifestyle of *Lampetra richardsoni* in Morrison Creek is the result of a delayed sexual maturation and possibly a delayed and incomplete metamorphosis (Youson and Beamish 1991). Based on this evidence from the Morrison Creek population, it has been suggested that the appearance of the two morphs within a single population may not necessarily represent an intermediate evolutionary transition but rather the sensitivity of lamprey metamorphosis to environmental factors (Youson 2002). It is hypothesized that the two forms may be the result of a recent heterochrony during metamorphosis which has effected the post metamorphic rate of sexual maturation (Youson 2002). This sensitivity to environmental factors and the change in developmental timing may explain both the success of lampreys and the presence of two adult life history types among lampreys as a group.

In any case, the presence of a parasitic variety of *Lampetra richardsoni* is of special significance to the scientific community as it demonstrates the very close relationship between the two life history types and has important implications to lamprey systematics (Beamish 1985; Beamish and Withler 1986). It appears to show that during metamorphosis, it is possible to direct the life history type into two directions. The occurrence of polymorphic populations such as the *Lampetra richardsoni* population found in Morrison Creek also confounds the use of life history type as a basis for defining species (Beamish and Withler 1986).

Limiting Factors

The survival of the Morrison Creek *Lampetra richardsoni* complex depends on the protection of the entire lamprey population and its habitat. There has been concern that rapid development in the area has overwhelmed the ability to protect sensitive habitat (Comox-Strathcona Sensitive Habitat Atlas 1995). Residential development has encroached on the mainstem of the creek and has resulted in an alteration of the riparian vegetation which poses a definite threat to fish habitat. A recent concern is the short-term and long-term effects of highway construction on fish habitat in Morrison creek. The British Columbia Ministry of Transportation and Highways has proposed to cross two sections of Morrison Creek sometime during 1999 (Lough et al. 1995a*,b*). The major fisheries concerns at these crossings are the potential loss of a considerable amount of fish habitat and the possible loss of fish passage at one of the crossings (Ship Environmental Consultants 1993).

Although mitigation options have proposed to replace habitat loss with an equal area of new habitat, it should not be assumed that all habitat conservation needs will be met in this way (Lough et al. 1995a*,b*; Knight and Blood 1997). It is important that existing fish populations are not compromised by mitigation and enhancement projects and that consideration is given to the effects of these activities on all species within the system.

Given the potential impacts of development pressures, the survival of *Lampetra richardsoni* in Morrison Creek is highly at risk. A significant loss of fish numbers in a presumably small population, combined with a considerable loss of habitat may prevent the survival of this rare species complex.

Evaluation

Due to its restricted distribution and threatened habitat, the polymorphic population of *Lampetra richardsoni* in Morrison Creek is both threatened and endangered. There is an urgent need to protect this most unusual and poorly understood species complex.

Acknowledgments

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Status of the Stickleback Species Pair, *Gasterosteus* spp., in Hadley Lake, Lasqueti Island, British Columbia*

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Hatfield, Todd. 2001. Status of the stickleback species pair, *Gasterosteus* spp., in Hadley Lake, Lasqueti Island, British Columbia. *Canadian Field-Naturalist* 115(4): 579–583.

Two species of threespine stickleback (*Gasterosteus* spp.) formerly inhabited Hadley Lake on Lasqueti Island, British Columbia, and are described briefly in this report. One species (referred to as “limnetic”) was a pelagic zooplankton feeder, and the other (referred to as “benthic”) exploited littoral zone benthic invertebrates. The species were unique British Columbia endemics restricted to this single lake. The species were first discovered in the late 1980s, but have recently become extinct following the unauthorized introduction of catfish (*Ameiurus nebulosus*) to the lake. Independently evolved yet morphologically similar species pairs exist elsewhere on nearby islands. Measures should be taken, such as transplanting to inaccessible fishless lakes, to protect the remaining species pairs.

Key Words: Gasterosteidae, sticklebacks, *Gasterosteus*, épinoches, Hadley Lake, Lasqueti Island, British Columbia, endangered species.

The Threespine Stickleback (*Gasterosteus aculeatus* complex) is a small (usually 35–55 mm) fish commonly found in marine and freshwater throughout the northern hemisphere. Marine sticklebacks are essentially identical throughout their range, whereas freshwater sticklebacks are ecologically, behaviorally and morphologically extremely variable. In general, *G. aculeatus* has a laterally compressed body and delicate pectoral and caudal fins. It is generally well-armored, getting both its latin and common names from different aspects of its armor. Sticklebacks have retractable pelvic and dorsal spines, and the body is protected by calcified lateral plates. Freshwater populations are highly variable in extent of armor but generally have many fewer lateral plates than the marine form. Body color also varies considerably from silvery to mottled green and brown. Sexually mature males develop bright red throats, though in some freshwater populations males turn completely black instead (McPhail 1969; Reimchen 1989).

At the end of the Pleistocene marine sticklebacks colonized freshwater repeatedly (Bell 1976). That is, each extant stream or lake population of sticklebacks is assumed to have arisen by an independent invasion from the sea (as opposed to a single colonization of one or a few bodies of freshwater followed by range expansion into previously uncolonized streams or lakes). Thus, the marine form is presumed to be the most recent ancestor to freshwater forms (Bell and Foster 1994). This scenario suggests that the tremendous variability we currently see in British

Columbia freshwater sticklebacks has arisen in approximately the last 10 000 to 13 000 years.

The British Columbia coastline is dotted with hundreds of small, low elevation lakes. Many of these lakes have been surveyed for sticklebacks (e.g., Lavin and McPhail 1985; Reimchen et al. 1985; Schluter and McPhail 1992; McPhail 1993) and most contain a single, albeit variable, form of stickleback (see e.g., Bell 1976; Lavin and McPhail 1985; Reimchen et al. 1985; Schluter and McPhail 1992). However, several lakes on islands in the Strait of Georgia are especially noteworthy because they each contain two distinct species (McPhail 1984, 1992, 1993, 1994; Schluter and McPhail 1992). The lakes are found on Texada Island, Lasqueti Island and Vancouver Island.

We refer to the two species in each lake as a “species pair”. The pattern of morphological and ecological divergence is remarkably similar in each of the lakes (Schluter and McPhail 1992). In each case, one of the species (referred to as “limnetic”) primarily exploits plankton, and has morphological traits such as a fusiform body, narrow mouth and many, long gill rakers (Figure 1). These traits are considered adaptations to a zooplankton-consuming lifestyle (Kliewer 1970; Magnuson and Heitz 1971; Sanderson et al. 1991; Schluter 1995). The other species (referred to as “benthic”) mainly exploits benthic invertebrates in the littoral zone, and has a robust body form (Figure 1), wide gape and few, short gill rakers, traits considered to be advantageous in benthic feeding (Schluter 1995).

Although limnetics and benthics have yet to be assigned formal scientific names there is no argument among researchers studying these fish that they warrant taxonomic status as distinct species. In each of the lakes limnetics and benthics co-exist and are

*Reviewed and approved by COSEWIC April 1999, status assigned to benthic and limnetic forms — Extinct.

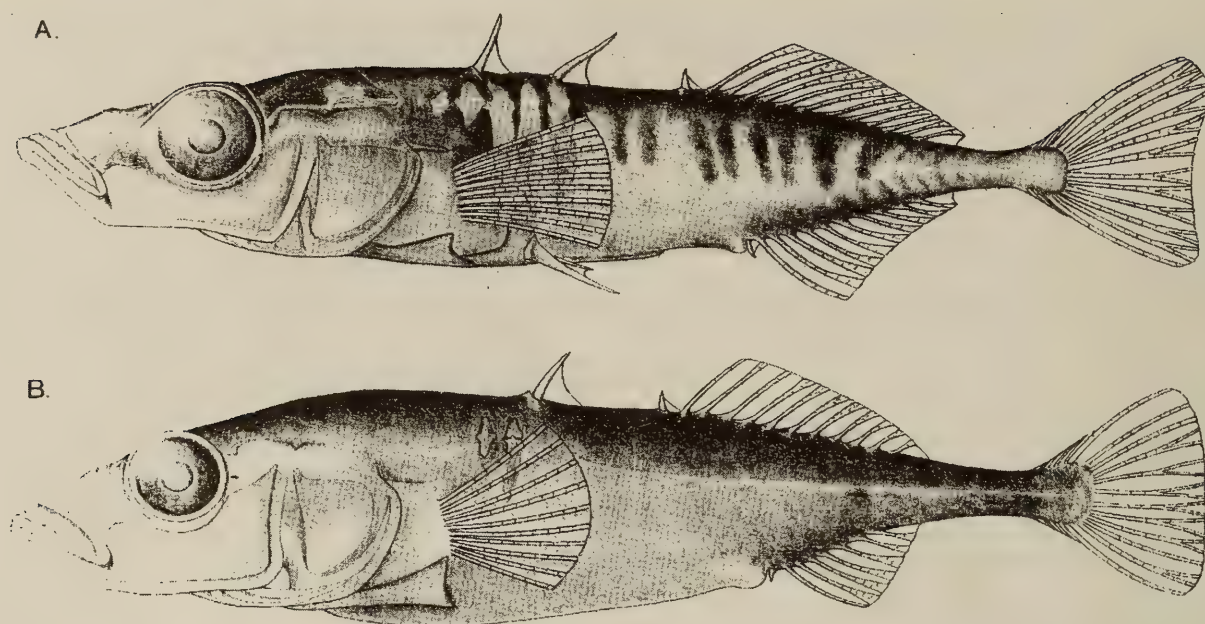


FIGURE 1. Limnetic (A) and benthic (B) forms of stickleback, *Gasterosteus* spp. (drawn by L. Nagel).

reproductively isolated by behavioral and genetic differences (McPhail 1984, 1992; Ridgway and McPhail 1984; Nagel 1994; Hatfield 1995, 1997; Hatfield and Schluter 1996). They therefore meet a conservative definition of species (Mayr 1942, 1963). One reason for the delayed naming of the species is that we have been awaiting good evidence of whether the species pairs are independently evolved or represent a single speciation with subsequent dispersal. That is, are we dealing with two species, or more? Geography and geological history are consistent with the hypothesis of independent evolution (McPhail 1993; 1994), but the best evidence will be a DNA-based phylogeny. Studies to construct such a phylogeny are underway and initial evidence suggests that the species pairs are indeed independently derived (McPhail 1993; Taylor et al. 1997; Taylor, unpublished data). Thus, the similar morphology and ecology of the pairs is due to parallel evolution, and we must name more than two species. Species pairs have some opportunity for dispersal through streams to adjacent lakes in the same watershed, though little opportunity for dispersal to other watersheds. It is therefore assumed that, since Hadley Lake is the only lake in its watershed, its sticklebacks represent distinct species.

Taxonomy

Taxonomic classification of British Columbia sticklebacks is highly complex, and presents one of the greatest challenges to systematists of British Columbia fish fauna. Freshwater populations of sticklebacks are invariably distinct from the marine form, yet they show both parallel evolution and remarkable phenotypic variation among sites (e.g., Hagen and Gilbertson 1972; Lavin and McPhail 1985; Reimchen

et al. 1985; Schluter and McPhail 1992; Bell and Foster 1994; McPhail 1994). Classical approaches to systematics rely on the measurement of morphological traits and assume that traits are never (or at least very rarely) evolved in parallel. Because parallel evolution is rampant in freshwater sticklebacks their taxonomy has been in chaos for some time (see e.g., Hagen and McPhail 1970). It is precisely this mix of parallel and independent phenotypic evolution that confounds taxonomists while at the same time intrigues ecologists and evolutionary biologists. It is now generally agreed that freshwater populations of sticklebacks have been derived from marine sticklebacks multiple times.

Modern molecular genetic techniques offer the most promising approach for resolving taxonomic issues in British Columbia sticklebacks. When constructing phylogenies, molecular data are used in much the same way as morphological data. The major difference is that the basic assumption of no parallel evolution is much more likely to be valid at a molecular level.

Studies using molecular approaches to stickleback taxonomy are currently underway. Regional patterns have been reported in Withler and McPhail (1985) and Orti et al. (1994). Finer scale issues (the most important issues for conservation biologists) are being researched primarily at labs at the University of British Columbia. It will be some time before data are complete and the issues resolved but early results have been reported in Taylor et al. (1997). These and unpublished data suggest that stickleback species pairs are genetically distinct units. However, more data are needed in order to understand the relationships among the different pairs and to determine which of the pairs are independently derived from the marine form, and

which represent replicate populations of the same species. Unfortunately, the Hadley Lake species pair became extinct before scientists could sample DNA from these fish. It is assumed that the considerable geographic isolation of the Hadley Lake sticklebacks indicates that they evolved independently from other species pairs. They should thus be named as two species distinct from other species pairs.

In reality the decision to award species status to an organism is subjective (McPhail and Carveth 1992). All of the limnetics and benthics studied to date meet conservative definitions of biological species (see Mayr 1942, 1963). For example, they maintain their morphological differences over several generations in a common environment (McPhail 1992; Hatfield 1995, 1997), they do not interbreed in the lab if given a choice among mates (Ridgway and McPhail 1984; Nagel 1994), and they have remained distinct in the wild despite some very large disturbances to their habitat (Larson 1976; McPhail 1994). Molecular data corroborate the view that benthics and limnetics are genetically different. Most biologists would not dispute that these are true species, albeit extremely young species.

Distribution

Hadley Lake, known locally as "Pete's Lake", is near False Bay, Lasqueti Island, British Columbia (Figure 2). To our knowledge the two species from Hadley Lake were restricted to this site ($49^{\circ} 30' \text{ N}$, $124^{\circ} 20' \text{ W}$). Other lakes on the island have been surveyed and do not contain species pairs.

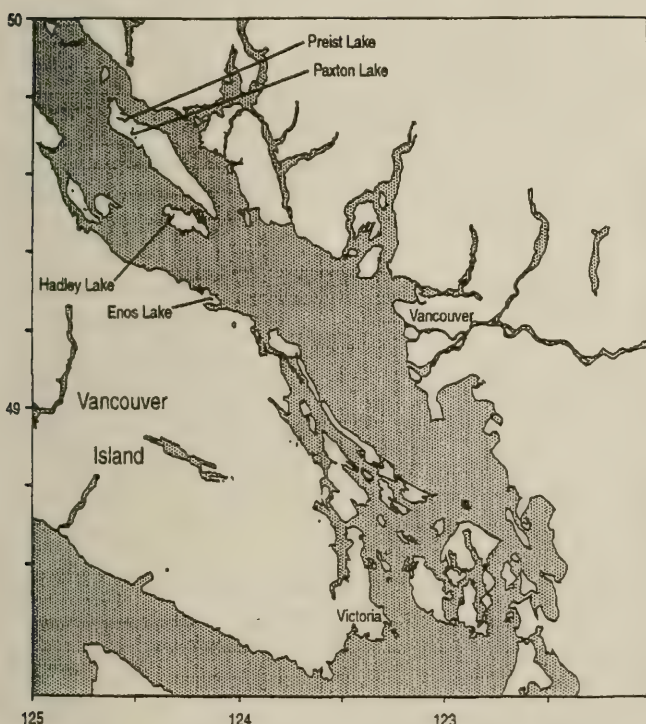


FIGURE 2. Map of the Strait of Georgia, British Columbia. Indicated are the major lakes in each of the four watersheds with species pairs.

Protection

There is currently no specific protection for any of the extant stickleback species pairs. Much of the potential for legislated protection of sticklebacks appears to depend on whether they are designated "endangered species" and whether proposed legislation gets enacted. The Fisheries Act, federal legislation that extends protection to fish and fish habitat, was originally written for the protection of extractive fisheries (i.e., commercial, recreational, aboriginal) and it is doubtful that it can be successfully applied to the extant stickleback species pairs. There is very little political support for protection of non-salmonid fish or non-game species in British Columbia.

Population Sizes And Trends

Sticklebacks have not been observed in Hadley Lake since the early 1990s and both species are now presumed extinct. Two separate expeditions have failed to observe a single stickleback despite considerable effort. Hadley Lake limnetics and benthics have been designated extinct by the British Columbia Conservation Data Centre. Specimens of Hadley Lake limnetics and benthics are held in the Fish Museum of the University of British Columbia.

Sometime in the early 1990s catfish (*Ameiurus nebulosus*) were introduced to Hadley Lake. Nocturnal nest predation by the catfish is the likely mechanism for the stickleback extinctions. Male sticklebacks will vigorously defend their nests during the day, but are poorly equipped to defend their nests at night. Catfish are not indigenous to this area; thus, sticklebacks have not co-evolved with this predator. Stickleback extinctions have occurred in other lakes following the introduction of catfish (McPhail 1989). The common pattern is that catfish numbers build until stickleback recruitment fails, leaving only an adult population that subsequently goes extinct within one or two years. Extinction can be alarmingly rapid: in the case of Hadley Lake it occurred before any conservation effort could be mounted.

Prior to catfish introductions the sticklebacks were under no apparent threat. Hadley Lake is small (~10 ha), but it likely supported large populations of both limnetic and benthic sticklebacks. However, no quantitative estimates of population size were attempted. McPhail (1989) estimated population sizes on the order of 100 000 for each of the species in Enos Lake, which is roughly twice the size of Hadley Lake. If Hadley Lake had half this number it would have been considered locally abundant by any standard.

Habitat

Hadley Lake is a small coastal lake typical of this region. It is ~50 m above sea level and is connected to the sea by ~1.2 km of stream. There is no permanent inlet stream for the lake and the outlet creek has been dammed and culverted. The hydrology of the outlet stream has been substantially modified by

road building and housing development. It is possible that the stream and lake had Cutthroat Trout (*Oncorhynchus clarki*) prior to these alterations.

The lake is lightly stained, and in the summer the littoral region is covered in dense beds of *Chara*, *Potamogeton* and *Utricularia*. There is a distinct pelagic zone in the lake, and in the summer plankton productivity is high. Catfish are presently the only fish species in the lake.

General Biology

The Hadley Lake stickleback species are the least studied of the known species pairs. They were not subjected to intense study in the way that species pairs from Enos and Paxton lakes have been. Although scientists believe that Hadley Lake limnetics and benthics were unique British Columbia endemics they were likely similar in ecology and behavior to the other species pairs. It is also assumed that they followed the general life history pattern of most *Gasterosteus* populations (for reviews of general stickleback biology see Wootton 1976; Bell and Foster 1994). The following brief description is based on the few observations of Hadley Lake sticklebacks in addition to observations of the other species pairs (see McPhail 1994 for review).

During the spring and summer months Hadley Lake limnetics were found in the open water where they foraged for plankton, and benthics were found in the littoral zone where they foraged for benthic invertebrates. During fall and winter months both species dispersed to deeper water. At maturity benthics were bigger on average than limnetics, and it is assumed that they lived longer than limnetics, perhaps forgoing reproduction in their first year in favor of growth. Limnetics reproduced at the end of their first year, and usually died before their second reproductive season.

Male sticklebacks are the sole providers of parental care. In the spring, both limnetics and benthics acquired territories in the littoral region where they built nests and mated (sometimes with many females). Following fertilization eggs took approximately 7–10 days to hatch, depending on the temperature. During this time males actively aerated the eggs by forward thrusts of their pectoral fins; embryos die if inadequately aerated (van den Assem 1967; Sargent and Gebler 1980). Males of both species vigorously defended their nests and territories from invaders (most often other sticklebacks) and continued to defend their young for about a week after they hatched. Sexual dimorphism was absent or minimal among benthics, but limnetic males tended to be bigger on average than limnetic females. Large male size enabled greater nest protection and territory defence (Rowland 1989).

Limiting Factors

Prior to the introduction of catfish to Hadley Lake there were no piscivorous fish, though herons (*Ardea*

herodias), kingfishers (*Megaceryle alcyon*) and loons (*Gavia immer*) are regularly seen in the area. Their effect on populations was likely minimal with the primary limiting factor being the capacity of the lake to produce plankton and benthos.

Special Significance of the Species

For more than 100 years one of the great questions in biology has been how diversity originates and is maintained. Speciation, the division of one species into two or more species, is the ultimate process giving rise to diversity. One major reason for our remarkably slow progress in understanding speciation has been that it usually occurs over vast time frames. It is therefore difficult to identify populations undergoing speciation until the process is complete or nearly complete. Furthermore, forces that maintain two species as distinct today are not necessarily the same forces that drove speciation several millennia ago.

For the student of speciation there are two exceptionally fascinating aspects of the biology of stickleback species pairs. The first is that the species are so young that it is reasonable to expect that the forces that drove speciation are the same forces that maintain their present reproductive isolation. These processes can therefore be studied in situ (e.g., Hatfield 1995; Schluter 1995). The second aspect is that similar speciation events have produced limnetic-benthic species pairs elsewhere on the coast, thus providing unheard of natural replication in studies of speciation. The loss of opportunity for further study of the Hadley Lake species pair is widely regarded as a scientific tragedy.

At a more local scale the ramifications of the loss of Hadley Lake sticklebacks depend on one's point of view. The loss of local biodiversity has been mourned from a purely aesthetic point of view. However, more tangible effects may be that there are more mosquitoes and midges in the region, and fewer piscivorous birds to watch.

Evaluation

Hadley Lake sticklebacks were among the most rare and endangered species in the world. The British Columbia Conservation Data Centre has designated them extinct. They should now be designated extinct by COSEWIC. For the reasons noted above these designations are justified.

Acknowledgments

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Status of the Stickleback Species Pair, *Gasterosteus* spp., in the Vananda Creek watershed of Texada Island, British Columbia*

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Hatfield, Todd. 2001. Status of the stickleback species pair, *Gasterosteus* spp., in the Vananda Creek watershed of Texada Island, British Columbia. *Canadian Field-Naturalist* 115(4): 584–590.

A pair of threespine stickleback species (*Gasterosteus* spp.) inhabit Balkwill, Emily and Priest Lakes (Vananda Creek watershed) on Texada Island, British Columbia. One species (referred to as “limnetic”) is a pelagic zooplankton feeder, and the other (referred to as “benthic”) is adapted for feeding on littoral zone benthic invertebrates. Current data suggest that limnetics and benthics are unique biological species and are restricted to this single watershed made up of three lakes.

Key Words: Gasterosteidae, sticklebacks, *Gasterosteus*, épinoches, Balkwill, Emily, Priest lakes, Vananda Creek, endangered species.

Threespine sticklebacks (*Gasterosteus aculeatus*) form a large group of species made up of thousands of phenotypically diverse populations. Typically sticklebacks are small (usually 35 to 55 mm) fish that are abundant in coastal marine and freshwater throughout the northern hemisphere. Marine sticklebacks are phenotypically similar throughout their range, whereas freshwater sticklebacks are ecologically, behaviorally and morphologically extremely variable. In general, *G. aculeatus* has a laterally compressed body and delicate pectoral and caudal fins. Individuals in most populations are well-armored—sticklebacks get both their latin and common names from different aspects of their armor.

Sticklebacks have retractable pelvic and dorsal spines, and their bodies are covered with calcified lateral plates. Freshwater populations are highly variable in extent of armor but generally have many fewer lateral plates than the marine form. Body color also varies considerably, from silvery to mottled green and brown. Sexually mature males in most populations develop bright red throats, although in a few freshwater populations males turn completely black instead (McPhail 1969; Reimchen 1989).

Many extant stream and lake populations of sticklebacks arose at the end of the Pleistocene (the most recent glaciation or “Ice Age”) via independent invasions from the sea (as opposed to a single colonization of one or a few bodies of freshwater followed by range expansion into previously uncolonized streams or lakes). Thus, the marine form is generally presumed to be the most recent ancestor to most freshwater forms (Bell and Foster 1994). This scenario suggests that the tremendous variability we currently

see in British Columbia freshwater sticklebacks has arisen within approximately the last 13 000 years.

The British Columbia coastline is dotted with hundreds of small, low elevation lakes. Many of these lakes have been surveyed for sticklebacks (e.g., Lavin and McPhail 1985; Reimchen et al. 1985; Schluter and McPhail 1992; McPhail 1993) and most contain a single, albeit variable, form of stickleback (see e.g., Bell 1976; Lavin and McPhail 1985; Reimchen et al. 1985; Schluter and McPhail 1992). However, several lakes on islands in the Strait of Georgia (see Figure 1) are especially noteworthy because they each contain two distinct species (McPhail 1984, 1992, 1993, 1994; Schluter and McPhail 1992). Balkwill, Emily, Priest and Paxton lakes are located on Texada Island (see Figure 2), Hadley Lake is located on Lasqueti Island, and Enos Lake is located on Vancouver Island. This report documents the current status of the species pair from Balkwill, Emily, and Priest lakes.

Description

We refer to the two species in each lake as a “species pair” (Figure 2). The pattern of morphological and ecological divergence is remarkably similar in each of the lakes (Schluter and McPhail 1992). In each case, one of the species (referred to as “limnetic”) primarily exploits plankton, and has morphological traits such as a fusiform body, narrow mouth and many, long gill rakers. These traits are considered adaptations to a zooplankton-consuming lifestyle (Magnuson and Heitz 1971; Kliewer 1970; Sanderson et al. 1991; Schluter and McPhail 1992, 1993). The other species (referred to as “benthic”) mainly exploits benthic invertebrates in the littoral zone, and has a robust body form, wide gape and few, short gill rakers, traits considered to be advantageous in benthic feeding (Schluter and McPhail 1992, 1993).

Although limnetics and benthics have yet to be assigned formal scientific names there is no argu-

*Reviewed and approved by COSEWIC April 1999, status assigned — Threatened.

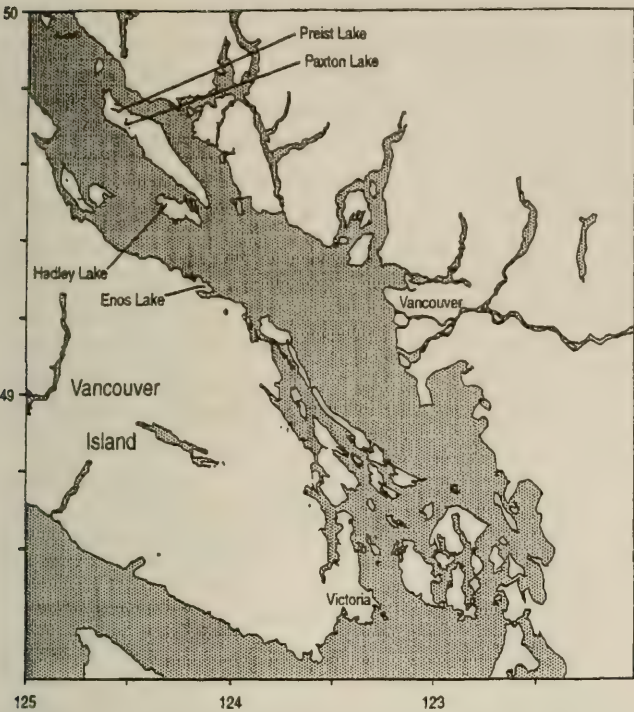


FIGURE 1. Map of the Strait of Georgia, British Columbia. Indicated are the major lakes in each of the four watersheds with species pairs.

ment among researchers studying these fish that they warrant taxonomic status as distinct species. In each of the lakes limnetics and benthics co-exist and are reproductively isolated by behavior and genetic differences (McPhail 1984, 1992; Ridgway and McPhail 1984; Nagel 1994; Hatfield 1995, 1997; Hatfield and Schluter 1996). They therefore meet a conservative definition of species (Mayr 1942,1963).

A primary reason for the delayed naming of the species is that we have been awaiting good evidence of whether the species pairs are independently evolved or represent a single speciation event with subsequent dispersal. Researchers are presently trying to determine if we are dealing with two species, twelve, or an intermediate number. Geography and geological history are consistent with the hypothesis of independent evolution (McPhail 1993; 1994), but the best evidence will be a DNA-based phylogeny.

Preliminary evidence suggests that the species pairs in several lakes are indeed independently derived (McPhail 1993; Taylor et al. 1997; Taylor unpublished data), while others likely represent replicate populations. We must therefore name more than two species. Species pairs have some opportunity for downstream and upstream dispersal to adjacent lakes in the same watershed suggesting the possibility of genetic exchange (see Figure 3). Current data suggest that the limnetics and benthics in Balkwill, Emily and Priest lakes (hereafter the Vananda Creek watershed) should be considered replicate populations of the same species pair. There is a pressing need to protect this species pair due to its extreme rarity.

Taxonomy

Taxonomic classification of British Columbia sticklebacks is highly complex, and presents one of the greatest challenges to systemicists of B.C. fish fauna. Freshwater populations of sticklebacks are invariably distinct from the marine form, yet they show both parallel evolution and remarkable pheno-

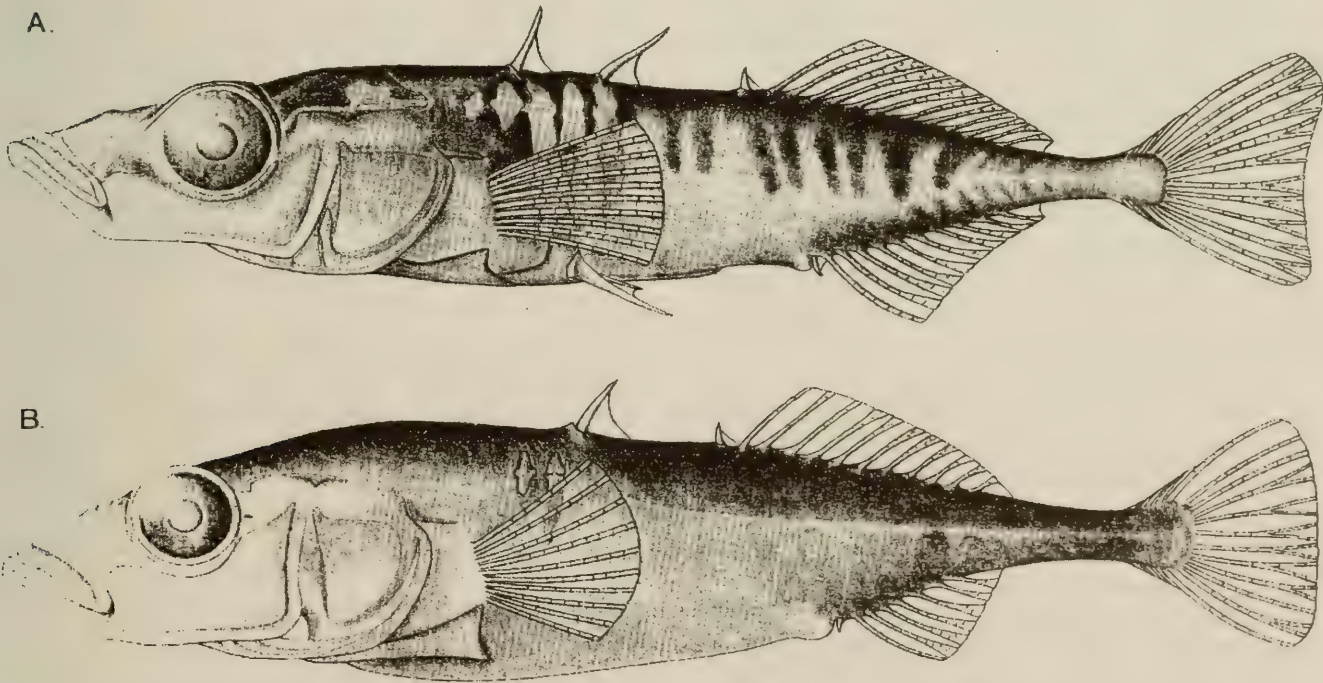


FIGURE 2. Limnetic (A) and benthic (B) forms of stickleback, *Gasterosteus* spp. (drawn by L. Nagel).

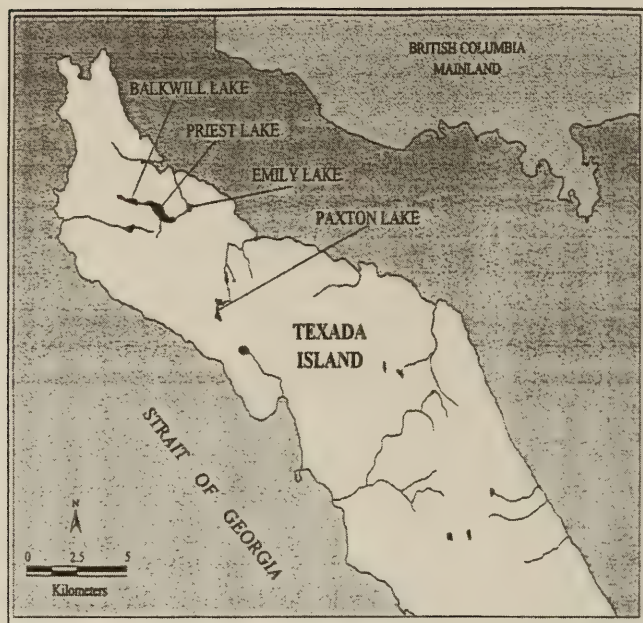


FIGURE 3. Northern portion of Texada Island showing the four lakes with Stickleback species pairs.

typic variation among sites (e.g., Lavin and McPhail 1985; Schluter and McPhail 1992; McPhail 1994; Hagen and Gilbertson 1972; Reimchen et al. 1985; Bell and Foster 1994). Classical approaches to systematics rely on the measurement of morphological traits and assume that traits are never (or at least very rarely) evolved in parallel. Because parallel evolution is rampant in freshwater sticklebacks their taxonomy has been in chaos for some time (see e.g., Hagen and McPhail 1970). It is precisely this mix of parallel and independent phenotypic evolution that confounds taxonomists while at the same time intrigues ecologists and evolutionary biologists. It is now generally agreed that freshwater populations of sticklebacks have been derived from marine sticklebacks multiple times.

Modern molecular genetic techniques offer the most promising approach for resolving taxonomic issues in B.C. sticklebacks. When constructing phylogenies, molecular data are used in much the same way as morphological data. The major difference is that the basic assumption of no parallel evolution is much more likely to be valid for molecular traits than for morphological traits.

Studies using molecular approaches to stickleback taxonomy are currently underway. Regional patterns have been reported in Withler and McPhail (1985) and Orti et al. (1994). Finer scale issues (the most important issues for conservation biologists) are being researched primarily at labs at the University of British Columbia. It will be some time before data are complete and the issues resolved but early results have been reported in Taylor et al. (1997). These and other unpublished data suggest that several of the stickleback species pairs are genetically distinct

units. More data are needed in order to understand the relationships among the different pairs and to fully understand which of the pairs are independently derived from the marine form, and which represent replicate populations of the same species.

In reality the decision to award species status to an organism is subjective (McPhail and Carveth 1992). All of the limnetics and benthics studied to date meet the definition of biological species (see Mayr 1942, 1963). For example, they maintain their morphological differences over several generations in a common environment (McPhail 1992; Hatfield 1995, 1997), they do not interbreed in the lab if given a choice among mates (Ridgway and McPhail 1984; Nagel 1994), and they have remained distinct in the wild despite some very large disturbances to their habitat (Larson 1976; McPhail 1994). Most biologists would not dispute that these are true species, albeit extremely young species.

Molecular data corroborate the view that benthics and limnetics are genetically different. However, the preliminary molecular genetic data are consistent with geographic data and suggest that Balkwill, Emily and Priest Lakes are inhabited by replicate populations of the same species pair. Together the three lakes represent the complete distribution of this species pair.

Distribution

Stickleback species pairs are currently confined to five low elevation coastal lakes on islands in the Strait of Georgia, southwestern British Columbia (Figures 1 and 3). A species pair formerly inhabited a sixth lake (Hadley Lake) on Lasqueti Island, but went extinct in the mid-1990s. Preliminary molecular genetic data suggest that limnetics and benthics in Balkwill Lake (49° 44' 90" N, 124° 35'), Emily Lake (49° 44' 80" N, 124° 32' 30"), and Priest Lake (49° 44' 80" N, 124° 33' 70"), of the Vananda Creek watershed, are genetically similar to one another. However, they are genetically distinct from species pairs found in other lakes. A conservative interpretation of these data is that these fish should be considered replicate populations of the same species pair. There are some differences among the three populations, but the differences are relatively small. Stickleback species pairs identical to those in the Vananda Creek watershed may exist elsewhere, but biologists have surveyed hundreds of lakes along the British Columbia, Washington, and Alaska coasts for these fish, and found them nowhere else. These sticklebacks thus appear to be unique British Columbia endemics.

Protection

There is currently no specific protection for sticklebacks in the Vananda Creek watershed. Much of the potential for legislated protection appears to rest

on whether they are designated “endangered species” and whether proposed legislation gets enacted. The Fisheries Act, federal legislation that extends protection to fish and fish habitat, was originally written for the protection of extractive fisheries (i.e., commercial, recreational, aboriginal) and it is doubtful that it can be successfully applied to sticklebacks in the Vananda Creek watershed.

The Forest Practices Code of British Columbia Act provides guidelines for riparian management around streams, lakes and fisheries sensitive zones on lands managed for forest harvest. However, the Code does not apply to private lands, and most lands around Balkwill, Emily and Priest lakes are privately owned.

The government of British Columbia has enacted the Fish Protection Act, and amended the Wildlife Act, and Water Act in an effort to protect fish and fish habitat. This legislation may substantially enhance the protection of the Vananda Creek watershed sticklebacks if they are designated “endangered species”. Once designated the Convention on International Trade in Endangered Fauna and Flora would also apply.

Population Sizes and Trends

Balkwill, Emily and Priest lakes each support large populations of both limnetic and benthic sticklebacks that have not been quantified. McPhail (1989) estimated population sizes on the order of 100,000 for each of the stickleback species in Enos Lake, which is larger than Emily and Balkwill lakes although smaller than Priest Lake. It is possible that Priest Lake supports more sticklebacks than Enos Lake.

Stickleback species pairs have been intensively studied by zoologists at University of British Columbia for the last two decades. However, the species pairs within the Vananda Creek watershed have received the least attention. Occasional trapping and study throughout this period suggests that populations have remained abundant and easy to trap in large numbers in baited Gee traps. This species pair should be considered locally abundant and under no immediate threat from population decline.

Habitat

Balkwill, Emily and Priest lakes are small (< 25 ha) coastal lakes typical of this region. Balkwill and Priest lakes are approximately 80 m above sea level, while Emily Lake is about 40 m in elevation. Although some maps show Balkwill and Priest lakes joined by a small stream, they are in fact connected by about 100 m of marsh that is sufficiently submerged during high water as to be passable by fish. Emily Lake is about 1 km downstream of Priest Lake, and connected to the sea by a further 2 km of stream. The hydrology of the entire system has been substantially modified by small dams, water extrac-

tion and land development (housing, road-building, mining).

Riparian areas in the watershed consist of mixed second growth forest. The lakes are lightly stained, and usually turbid. In summer the littoral region is covered in dense beds of *Chara*, *Potamogeton* and *Utricularia*. Emergent littoral vegetation is dominated by *Juncus* and *Nuphar*. There is a distinct pelagic zone in each lake, and in the summer plankton productivity is high. All three lakes have a good supply of large woody debris in the littoral zone.

General Biology

Life History — Limnetics

Sticklebacks in the Vananda Creek watershed are the least-well studied of all the species pairs. However, based on the studies that have been undertaken (e.g., Schluter and McPhail 1992, 1993; Nagel 1994; McPhail unpublished data) their life history is assumed to be very similar to the other species pairs. Much of the following description is therefore based on studies carried out on the species pairs found in Paxton and Enos lakes.

The stickleback species pairs in Balkwill, Emily and Priest lakes follow the general life history pattern of most *Gasterosteus* populations (for reviews of general stickleback biology see Wootton 1976; Bell and Foster 1994), but some aspects of limnetic and benthic life histories are divergent from each other. Limnetics can be considered “live fast and die young” species, whereas benthics devote considerably more energy to growth and longevity.

Limnetics are generally sexually mature after one year and rarely live beyond two years. There is considerable sexual dimorphism: reproducing males tend to be bigger on average than gravid females. Large male size enables greater nest protection and territory defense (Rowland 1989). Fecundity relationships for Paxton Lake limnetics are shown in Hatfield (1995), with typical fecundity about 30–40 eggs per clutch. In the lab, females produce several clutches per season, usually in close succession if food availability is high (personal observation). Female life history is likely similar in the wild.

As with other sticklebacks, limnetic males are the sole providers of postzygotic parental care. In the spring, they acquire territories in the littoral region where they build nests and mate (sometimes with many females). Limnetics prefer unvegetated, open nesting locations (McPhail 1994; Hatfield and Schluter 1996). They often nest in less than 1 m of water on submerged logs, in shallow bays with gravel or rocky substrates, and on firm muddy substrate. Because preferred spawning habitat is not uniformly distributed in the littoral zone, nesting males are clumped in their distribution. Despite the fact that limnetics and benthics breed at the same time of year they rarely interbreed (McPhail 1994).

Following fertilization, eggs take approximately

7–10 days to hatch, depending on temperature. During this time males actively aerate the eggs by thrusts of their pectoral fins; embryos die if inadequately aerated (van den Assem 1967; Sargent and Gebler 1980). Male sticklebacks vigorously defend their nests and territories from invaders (most often other sticklebacks) and continue to defend their young for about a week after they hatch. The young then disperse into the littoral vegetation where they feed under cover. By late summer limnetics have become large and swift enough to escape predators, and their spines have grown big enough to act as a deterrent. At this time they school up and forage for plankton in the open water.

Life History — Benthics

As with the above section on limnetics, much of the following description of benthic life history is based on studies carried out on the species pairs found in Paxton and Enos lakes. Benthic sticklebacks in the Vananda Creek watershed have a general life history pattern consistent with most *Gasterosteus* populations. However, benthics are divergent from limnetics. On average, benthics live longer and reproduce less often than limnetics. Determining the age of sticklebacks is difficult, but benthics do not seem to become sexually mature after one year, and appear to live well beyond two years, perhaps as long as seven years (McPhail, personal communication). There is little or no sexual dimorphism in benthics, if present it tends to be in the opposite direction from the limnetics: reproductive males tend to be smaller on average than gravid females. Fecundity relationships for Paxton Lake benthics are shown in Hatfield (1995); but are likely representative of benthics from other lakes. In the lab, females produce only one or two clutches per season, regardless of food availability (personal observation). Females probably have a similar life history in the wild.

Benthics prefer densely vegetated nesting locations, usually among beds of *Chara* (McPhail 1994; Hatfield and Schluter 1996). Their nests are highly concealed and difficult to find in the field. They tend to nest in water of greater depth than limnetics, though usually less than 2 m depth. As with limnetics, preferred spawning habitat for benthics is not uniformly distributed so nesting benthic males are clumped in their distribution.

Benthics are similar to limnetics in all aspects of parental care and development. About a week after they hatch, the young disperse into the littoral vegetation where they feed. Juvenile benthics continue to feed in the shallow littoral zone under cover of, or within close proximity to vegetation cover.

Diet

Diets of limnetics and benthics have been well studied for later life history stages during spring summer and early fall (Schluter and McPhail 1992;

Schluter 1995). Very little is known about diets during the initial life stages of the two species, or what all life stages eat during late fall and winter months.

As adults, limnetic and benthic sticklebacks eat quite different foods. Limnetics feed primarily in the surface waters away from the lake margins. There they hunt in loose schools for copepods, cladocera and insect larvae. Males will often forage for benthos when nesting in the littoral zone. As young juveniles, limnetics feed at the lake edges among reeds and submerged plants where they can seek cover if approached by a potential predator.

Benthics on the other hand forage along the shallow margins of the lake for larger prey such as snails, clams, dragonfly nymphs, amphipods, and chironomids. These invertebrates are found among a variety of substrates including plants, rocks or mud. Benthics likely eat similar food types throughout their life, but gradually shift to larger prey as they get bigger themselves.

Species Movement

There are three movement trends of note within other lakes with species pairs that are assumed to reflect movements within Balkwill, Emily and Priest lakes. In early to mid fall most individuals are found in deeper waters where they remain during the winter months. During the spring spawning months adults of both species are abundant in the shallow littoral zone; however limnetic females tend to forage in the surface pelagic zone and move into the littoral zone to seek nesting males. During the summer months limnetics are found in the pelagic zone and benthics are found in the shallow littoral zone. These movements are minor, and are unlikely to have significant bearing on management options for the species, at least at present.

Adaptability

Historically the Vananda Creek watershed has been impacted by significant human disturbance, including damming the outlet stream draining Priest Lake, water extraction for mining and residential use, and land clearing associated with mining, forest harvest and human settlement. Limnetics and benthics within each of the lakes have been tolerant of these disturbances. Water extraction has likely been the most significant disturbance — lake level fluctuations can affect water quality, spawning habitat, predation, food resources, and cover. In reality, we know little about the response of the sticklebacks to these and other disturbances except that they were resilient enough to persist.

Introduction of non-native species likely presents the most significant immediate threat to the species pair in Balkwill, Emily and Priest lakes. The only disturbance known to have led to the extinction of a species pair is the unauthorized introduction of catfish (*Ameiurus nebulosus*) to Hadley Lake on Lasqueti Island. In that case extinction was swift.

Limiting Factors

Current limits to stickleback abundance in Balkwill, Emily and Priest Lakes are poorly understood. For example, it is not known whether abundance is limited by rearing habitat, food production, cover, predation, spawning habitat or other factors. Currently limnetics and benthics are locally very abundant in each lake, and are not apparently in decline.

The lakes are inhabited by numerous invertebrates that feed on young sticklebacks, and are regularly visited by piscivorous birds (e.g., herons (*Ardea herodias*), kingfishers (*Megaceryle alcyon*) and loons (*Gavia immer*)). Cutthroat Trout (*Oncorhynchus clarki*) also live in the lakes and are predatory. However, their presence is not a threat to the sticklebacks.

Based on anecdotal evidence it seems unlikely that the abundance of sticklebacks in these lakes is limited by spawning habitat. Both species have preferred spawning habitat types within the littoral zone (McPhail 1994; Hatfield and Schluter 1996), but during the spawning season nesting males are very abundant, and nesting success and recruitment appear to be high (personal observation).

The primary limiting factor at present is most likely food supply, the capability of the lake to produce plankton and benthos. Balkwill, Emily and Priest lakes are very productive and therefore can and do support large numbers of sticklebacks.

Special Significance of the Species

The special significance of the Balkwill, Emily and Priest lakes species pair is primarily of aesthetic and scientific value. It is very unlikely that the species will be of commercial use and value.

Stickleback species pairs are widely regarded as a scientific treasure, in large part because they are among the youngest species on earth. Scientists believe they have evolved since the end of the last glaciation, approximately 13 000 years ago. The production of a new species usually takes in the order of millions of years. The speed with which these distinct fish species evolved has intrigued and excited scientists from around the world. They are a remarkable research subject that will help us understand the biological and physical processes that have given us the tremendous diversity of organisms we see around us. Newspapers, magazines and scientific journals have published the story of the discovery of these species, and have followed the results of ongoing scientific studies.

Evaluation

Limnetic and benthic sticklebacks in Balkwill, Emily and Priest Lakes are among the most rare and endangered species in the world, and should be designated endangered species (i.e., Red Listed) by COSEWIC. Unlike many species that are rare in

Canada but found elsewhere, stickleback species pairs exist nowhere else. Their entire worldwide distribution is highly restricted, with no potential for natural dispersal to suitable habitat elsewhere. All of the species pairs occur only in a fast-growing region of southwestern British Columbia. Although the lakes are in relatively undeveloped areas of the province, they have already been affected by human activities such as logging, land clearing, water removal, road building, and septic tank inputs. The sudden extinction of the Hadley Lake species pair emphasizes the extreme susceptibility of these fish to introductions of exotic species.

The British Columbia Conservation Data Centre has placed stickleback species pairs, including the species pair in Balkwill, Emily and Priest Lakes, in the highest risk category, Category 1: "critically imperiled because of extreme rarity". The species have been placed on the provincial Red List as threatened or endangered. For the reasons noted above these designations are justified.

Acknowledgments

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Status of the Stickleback Species Pair, *Gasterosteus* spp., in Paxton Lake, Texada Island, British Columbia*

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A pair of threespine stickleback species (*Gasterosteus* spp.) coexists in Paxton Lake on Texada Island, British Columbia. One species (referred to as “limnetic”) forages on pelagic zooplankton, and the other (referred to as “benthic”) feeds on littoral zone benthic invertebrates. The morphology of each species reflects divergent resource use strategies. For example, benthics are larger, have wider mouths and fewer, shorter gill rakers than limnetics. Benthics also have considerably less armour than limnetics. Current data suggest Paxton Lake limnetics and benthics are unique biological species. Although both species are numerous, their entire distribution is restricted to this single lake. The immediate threat to these stickleback species is the unauthorized introduction of a non-native predator such as catfish (*Ameiurus nebulosus*) or Pumpkinseed (*Lepomis gibbosus*).

Key Words: Gasterosteidae, sticklebacks, *Gasterosteus*, épinoches, Paxton, endangered species

Threespine sticklebacks (*Gasterosteus aculeatus* complex) form a taxonomically difficult group composed of thousands of phenotypically diverse populations. They are abundant, small fish (usually 35–55 mm) found in coastal marine and fresh water throughout the Northern Hemisphere. Marine sticklebacks are phenotypically similar throughout their range, whereas freshwater sticklebacks are ecologically, behaviourally, and morphologically variable (e.g., Lavin and McPhail 1985; Schluter and McPhail 1992; McPhail 1994; Hagen and Gilbertson 1972; Reimchen et al. 1985; Bell and Foster 1994). In general, *G. aculeatus* has a laterally compressed body, well armoured by calcified lateral plates and retractable pelvic and dorsal spines, with delicate pectoral and caudal fins. Freshwater populations are highly variable in extent of armour but generally have fewer lateral plates than the marine form. Body colour also varies considerably, from silvery to mottled green and brown. Usually sexually mature males develop bright red throats, although in a few freshwater populations males turn completely black (McPhail 1969; Reimchen 1989).

The marine form is the most recent ancestor to most freshwater forms (Bell and Foster 1994). Sticklebacks did not colonize fresh water in one single event followed by a range expansion; they invaded fresh water repeatedly following deglaciation. This suggests that the tremendous variability currently seen in British Columbia's freshwater

Gasterosteus has arisen in the last 10 000 to 13 000 years.

Many of the hundreds of small, low elevation, coastal lakes found in British Columbia have been surveyed for sticklebacks (e.g., Lavin and McPhail 1985; Reimchen et al. 1985; Schluter and McPhail 1992; McPhail 1993). Most contain a single, variable, form of stickleback (see e.g., Bell 1976; Lavin and McPhail 1985; Reimchen et al. 1985; Schluter and McPhail 1992). Six lakes found on islands in the Strait of Georgia (see Figure 1) are especially noteworthy. Two distinct species evolved in each of these lakes (McPhail 1984, 1992, 1993, 1994; Schluter and McPhail 1992). The pattern of morphological and ecological divergence shown by the sticklebacks is remarkably similar in each of the lakes (Schluter and McPhail 1992). In each case, one of the species (referred to as “limnetic”) displays morphological traits (such as a fusiform body, narrow mouth and many, long gill rakers) best suited for foraging on zooplankton (Magnuson and Heitz 1971; Kliever 1970; Sanderson et al. 1991; Schluter and McPhail 1992, 1993). The other species (referred to as “benthic”) exploits benthic invertebrates in the littoral zone. It has a robust body form, wide gape and a few, short gill rakers, traits considered advantageous for benthic feeding (Schluter and McPhail 1992, 1993).

These “species pairs” have been discovered in Paxton, Priest, Balkwill and Emily lakes located on Texada Island, Hadley Lake on Lasqueti Island, and Enos Lake on Vancouver Island (Figures 2 and 3). The pair that occurred in Hadley Lake is now considered extinct. In each of the remaining occurrences limnetics and benthics co-exist and are reproductively isolated by behaviour and genetic differences

*Reviewed and approved by COSEWIC April 1999, status assigned — threatened.

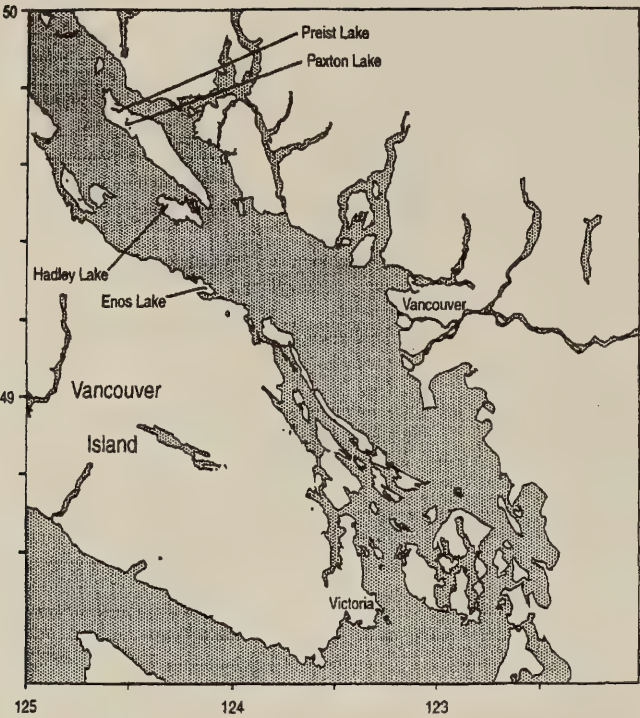


FIGURE 1. Map of the Strait of Georgia, British Columbia. Indicated are the major lakes in each of the four watersheds with species pairs.

(McPhail 1984, 1992; Ridgway and McPhail 1984; Nagel 1994; Hatfield 1995, 1997; Hatfield and Schluter 1996) meeting a conservative definition of species (Mayr 1942, 1963). Species description and naming have been delayed until completion of a DNA-based phylogeny. Preliminary genetic evidence suggests that the species pairs in several lakes are independently derived (McPhail 1993; Taylor et al. 1997, Taylor unpublished data).

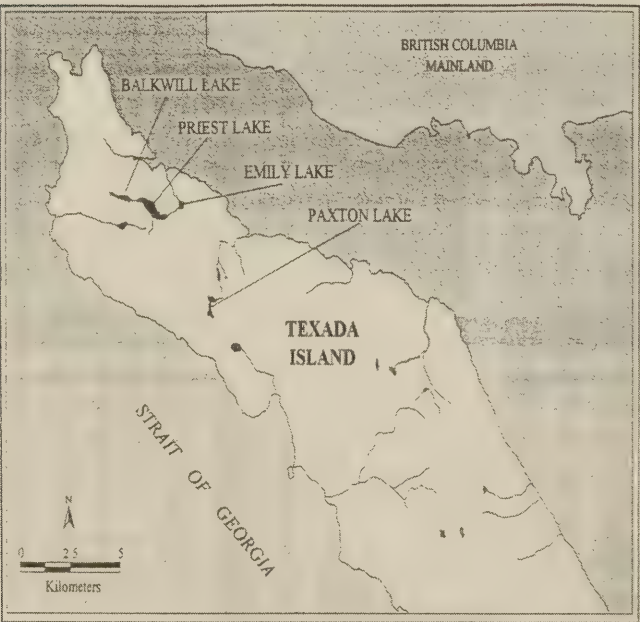


FIGURE 2. Northern portion of Texada Island showing the four lakes with Stickleback species pairs.

This report documents the current status of the species pair found in Paxton Lake. Reports on the current status of stickleback species found in Hadley Lake, and in Balkwill, Emily and Priest lakes have also been prepared. A status report on the Enos Lake species pair was completed earlier (McPhail 1989) and should be updated.

Distribution

Paxton Lake (49° 42' 30" N, 124° 31' 30" W) shares a watershed with two smaller lakes, Myrtle and Case lakes, as well as Rumbottle Creek (the outlet of Paxton). Only Paxton Lake contains a species pair. Based on surveys of hundreds of lakes along the coast of Alaska, British Columbia, and Washington, both Paxton Lake species appear to be unique British Columbia endemics.

Protection

Currently, there is no specific protection for Paxton Lake sticklebacks. The provisions of the federal Fisheries Act, originally intended to protect extractive fisheries, do not apply to the protection of fish that do not contribute to a fishery. The government of British Columbia has enacted the Fish Protection Act containing consequential amendments to the Wildlife Act designed to provide some protection for species designated under the Act. The amendments extend provisions for endangered and threatened wildlife to fish, and to aquatic invertebrates and plants that are a factor in fish habitat. For example, causing lasting harm to, or intentionally causing harm to endangered or threatened species would become an offence. Once designated the Convention on International Trade in Endangered Species of Wild Fauna and Flora could also be applied, if it became necessary.

Population Size(s) and Trends

Paxton Lake supports unquantified but large populations of both limnetic and benthic sticklebacks. It is roughly the size of Enos Lake where McPhail (1989) estimated population sizes on the order of 100,000 per species. Current abundance in Paxton may be higher than historic levels as a dam on the outlet has prevented reproduction of piscivorous native Cutthroat Trout (*Oncorhynchus clarki*). Over the last decade both sticklebacks have remained abundant and easy to trap in large numbers, indicating the populations are currently stable. Severe declines may have occurred historically.

Habitat

General Description

Paxton Lake is a small (17 ha) coastal lake with a maximum depth of about 15 m. The lake has distinct littoral and pelagic zones. It lies about 90 m above sea level and is connected to the sea by roughly

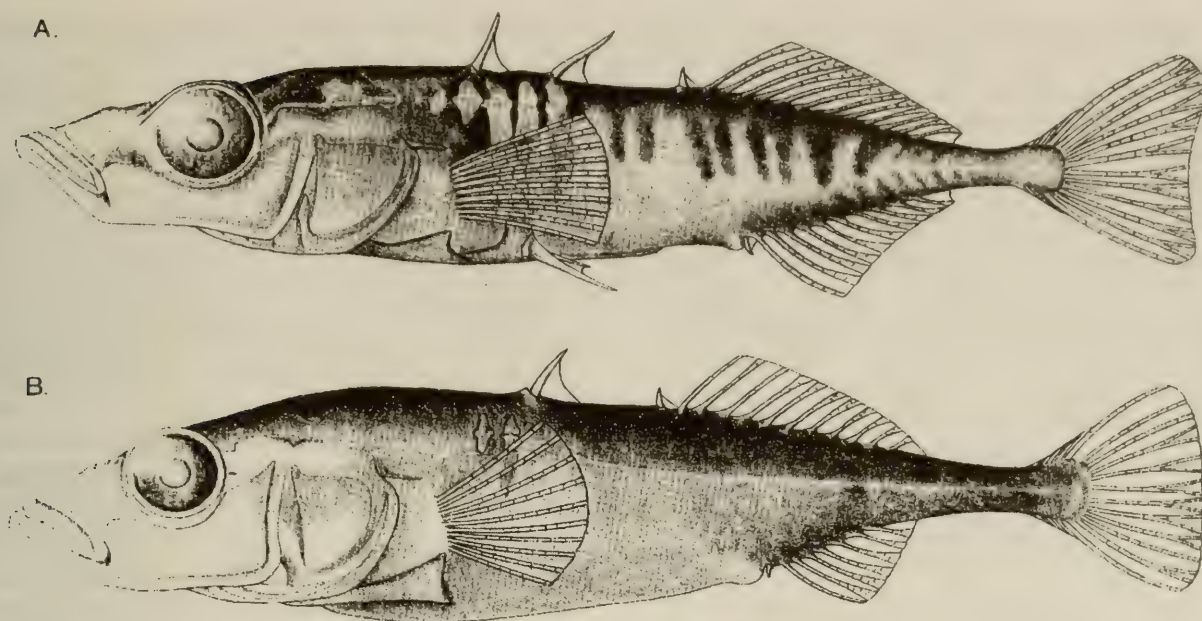


FIGURE 3. Limnetic (A) and benthic (B) forms of stickleback, *Gasterosteus* spp., (drawn by L. Nagel).

4.5 km of stream. There is no permanent inlet stream to the lake. Rumbottle Creek was dammed in 1956 to provide a source of water for a nearby mine. Prior to dam construction Paxton Lake was actually two separate lakes, joined by about 100 m of stream. Raising the water level by 1.5 m combined the two lakes into one with a narrow waist and two fairly equal basins (McPhail 1992).

Rumbottle Creek drops about 80 m, in a series of small falls, over the last 2 km of its length before entering Malaspina Strait. The falls effectively isolate the upper portions of the creek and the lake from the sea. Much of its length has been affected by development (housing, road-building, culverts, etc.) and logging.

Paxton Lake lies in limestone overlain by post-glacial marine sediments. Substrate at the south end is predominantly marl (Larson 1976). Riparian areas consist of mixed second growth forest. Lake water is lightly stained. Summer conditions described by Larson (1976) indicate surface water temperatures can reach 23°C, a thermocline develops between 2 to 5 m. The littoral region becomes covered in dense beds of *Chara*, *Potamogeton* and *Utricularia*. Emergent littoral vegetation is dominated by *Juncus* and *Nuphar*. Plankton productivity is high.

Habitat Use

Limnetics feed primarily in the pelagic zone. In the spring males move inshore and select unvegetated, open nest sites (McPhail 1994; Hatfield and Schluter 1996). They often nest in less than 1 m of water on submerged logs, in shallow bays with gravel or rocky substrates, or on firm muddy substrate. Patchy distribution of preferred spawning habitats may lead to clustering of nest sites.

Benthics feed over open mud bottom or submerged aquatic vegetation. Males build their nests in dense vegetation, usually in beds of *Chara* (McPhail 1994; Hatfield and Schluter 1996). Their nests are highly concealed and difficult to find. They tend to nest in water of greater depth than limnetics, though usually less than 2 m. Spawning males congregate in areas of preferred habitat.

About a week after hatching, the young of both species disperse into the littoral vegetation where they feed under cover. Juvenile benthics continue to feed in the shallow littoral zone or within close proximity to vegetation. By late summer the limnetics school up and move into the open water since they have the speed and spines to escape predators.

By late fall most individuals of both species have moved to deeper water where they spend the colder months.

General Biology

Life History

Both Paxton Lake stickleback species follow the general life history pattern of most *Gasterosteus* populations (for reviews of general stickleback biology see Wootton 1976; Bell and Foster 1994). Although limnetics and benthics breed at the same time of year (April–June), they rarely interbreed (McPhail 1992). As with other sticklebacks, males are the sole providers of postzygotic parental care. In the spring, males acquire territories in the littoral region where they build nests and mate (sometimes with many females). Following fertilization, eggs take approximately 7–10 days to hatch, depending on water temperature. During this time males actively aerate the eggs by thrusts of their pectoral fins; embryos die if inadequately aerated (van den Assem

1967; Sargent and Gebler 1980). Male sticklebacks vigorously defend their nests and territories from invaders (often other sticklebacks) and continue to defend their young for about a week after they hatch. In other aspects limnetic and benthic life histories are divergent from each other. Limnetics are relatively short lived, whereas benthics devote considerably more energy to growth and longevity. Limnetics are generally sexually mature after one year and rarely live beyond two years. There is considerable sexual dimorphism; reproducing males tend to be bigger on average than gravid females. Fecundity relationships are shown in Hatfield (1995), but typical fecundity is about 30–40 eggs per clutch for a limnetic female. In the lab, females produce several clutches per season, usually in close succession if food availability is high (Hatfield, personal observation).

Benthics generally live longer and reproduce less frequently than limnetics. Determining the age of sticklebacks is difficult, but Paxton Lake benthics do not seem to mature until their second year, and may live as long as seven years (McPhail, personal communication). There is little or no sexual dimorphism in benthics, if present it tends to be in the opposite direction from the limnetics (i.e., reproductive males may be slightly smaller than gravid females). Fecundity relationships for benthics are shown in Hatfield (1995); females often carry more than 150 eggs. In the lab, females produce only one or two clutches per season, regardless of food availability (Hatfield, personal observation).

Diet

Diets of both species have been well studied during the spring, summer, and early fall for later life history stages (Schluter and McPhail 1992; Schluter 1995). Little is known about diet during early life stages, or the late fall and winter months.

Adult limnetic and benthic sticklebacks consume quite different foods. Limnetics feed primarily in the surface waters away from the lake margins. They hunt in loose schools for copepods, *Daphnia* and insect larvae. Males forage for benthos while nesting and often consume eggs from the nests of other males.

Benthics forage along the shallow margins of the lake for larger prey such as snails, clams, dragonfly nymphs, amphipods, and chironomids. These invertebrates are found among a variety of substrates including plants, rocks or mud. Benthics likely eat similar items throughout their life, selecting larger sized prey as they grow.

Limiting Factors

Limits to Paxton Lake stickleback abundance are poorly understood. Piscivorous cutthroat trout are no longer a consideration. Other predators include

numerous invertebrates that feed on young sticklebacks, and piscivorous birds [e.g., herons (*Ardea herodias*), kingfishers (*Megaceryle alcyon*) and loons (*Gavia immer*)]. Their presence does not appear to be a significant factor. Each species has different spawning habitat preferences (McPhail 1994; Hatfield and Schluter 1996). However, recruitment does not seem to be restricting population numbers as nesting males are very abundant, and nesting success appears high (Hatfield, personal observation). Food supply may be the current limiting factor.

Threats

Historically Paxton Lake has been subjected to tremendous human disturbance. Although Paxton Lake limnetics and benthics have survived, each of the disturbances undoubtedly had an influence on their numbers and relative abundance. Water extraction for a nearby mine and the introduction of salmonids likely had the most profound effects, and may have led to considerable hybridization between the two species (McPhail, personal communication). Fluctuations in water level would affect water quality, spawning habitat, predation, food resources, and cover. Water removal ceased following closure of the mine but could recur. The introduction of large numbers of Coho Salmon (*Oncorhynchus kisutch*) may have had a significant effect on food resources and predation. Provincial fisheries managers are now aware of the presence of the sticklebacks and will not authorize further fish introductions.

However, the unauthorized release of non-native fish species in the watershed is a significant immediate threat to both species. The species of most concern are catfish (*Ameiurus nebulosus*) or Pumpkinseeds (*Lepomis gibbosus*). Both exotics appeared on Vancouver Island and the mainland in the early 1900s, and continue to spread through unauthorized public transplants. Catfish are nocturnal nest predators; pumpkinseeds act as predators and competitors at different life history stages. The only disturbance known to have led to the extinction of a stickleback species pair was the release of catfish (*Ameiurus nebulosus*) to Hadley Lake on Lasqueti Island, immediately west of Texada Island. In that case extinction was swift. Populations of both exotic species have become established in close proximity to Texada Island.

Special Significance of the Species

Paxton Lake sticklebacks are significant for aesthetic and scientific reasons. Stickleback species pairs are widely regarded as scientific treasures. Scientists believe they have evolved since the end of the last glaciation, approximately 13 000 years ago, making them some of the youngest species on the planet. The speed with which these species pairs evolved has intrigued and excited scientists around the world. They are remarkable subjects for the study of specia-

tion and evolution. The public has also followed stories about the species pairs in the popular press and on television.

Evaluation

The sudden extinction of the Hadley Lake species pair emphasizes the extreme susceptibility of these fish to introductions of exotic species. Unlike many species that are rare in Canada, the Paxton Lake stickleback species occur nowhere else. There is no potential for natural dispersal to suitable habitat elsewhere. They occur in a region of southwestern British Columbia experiencing rapid urbanization. Although the lake lies in a relatively undeveloped area, the drainage has been affected by various human activities including mining, logging, land clearing, water removal, road building, septic effluent, and introduction of non-native species.

The British Columbia Conservation Data Centre has ranked both Paxton Lake sticklebacks as G1/S1 (critically imperiled because of extreme rarity), using the system developed by The Nature Conservancy. These species have also been placed on the provincial Red List, the highest risk category.

Acknowledgments

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Rapport sur la Situation du Brochet d'Amérique, *Esox americanus americanus*, au Canada*

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In Canada, the Redfin Pickerel (*Esox americanus americanus*), is restricted to Quebec. The first Canadian record of Redfin Pickerel dates back to 1944. Its distribution is limited to the St. Lawrence River, between the Verchères Islands and the mouth of the Godefroy River; Lake St. Paul; and the drainages of the Richelieu River, including Lake Champlain, the St. François River and the Yamaska River. The abundance of the Redfin Pickerel is difficult to assess because it is able to escape from several types of gear commonly used in fish surveys. Further, it prefers shallow grass beds, in which intensive inventories are seldom conducted. The only well-established populations seem to be those of the Upper Richelieu River and the Berthier Islands, where its abundance is stable. The primary threats to the survival of the Redfin Pickerel are believed to be dyke construction on farmland to prevent spring flooding and the drainage of grass beds. This subspecies has not been given any special protective status and is not the subject of specific regulations. There are, however, a few protected areas within its range, and the Quebec Act on the Conservation and Development of Wildlife protects fish habitat located on public land. The Redfin Pickerel has no commercial value.

Au Canada, la sous-espèce de la famille des Ésocidés connue sous le nom de brochet d'Amérique (*Esox americanus americanus*) est exclusive au Québec. La première mention du brochet d'Amérique au Canada date de 1944. Son aire de répartition est limitée au fleuve Saint-Laurent entre les îles de Verchères et l'embouchure de la rivière Godefroy, au lac Saint-Paul, ainsi qu'aux réseaux hydrographiques des rivières Richelieu, incluant le lac Champlain, Saint-François, et Yamaska. L'abondance du brochet d'Amérique est difficile à évaluer puisqu'il échappe à plusieurs engins de pêche couramment utilisés lors des inventaires ichtyologiques. De plus, il préfère les herbiers de faibles profondeurs qui ne font pas toujours l'objet d'inventaires très intensifs. Les seules populations bien établies semblent être celles du Haut-Richelieu et des îles de Berthier, où l'abondance serait stable. Les principales menaces à la survie du brochet d'Amérique seraient l'endiguement des terres agricoles pour prévenir l'inondation printanière et l'assèchement des herbiers. Cette sous-espèce ne jouit pas de protection particulière et ne fait pas l'objet de réglementation spécifique. Il existe quelques territoires protégés sur son aire de répartition, et la Loi sur la conservation et la mise en valeur de la faune du Québec protège l'habitat du poisson sur les territoires publics où elle est présente. Le brochet d'Amérique n'a pas de valeur économique.

Mots clés: brochet, brochet d'Amérique, Redfin Pickerel, *Esox americanus americanus*, Québec, Esocidae espèces en péril.

Le présent rapport vise à établir le statut du brochet d'Amérique (*Esox americanus americanus* Gmelin 1788) au Canada. Cette sous-espèce a été placée sur la liste des espèces susceptibles d'être désignées menacées ou vulnérables par le ministère de l'Environnement et de la Faune du Québec (Beaulieu 1992). Les raisons qui ont justifié cette classification sont les suivantes : elle est à la limite de son aire de répartition, elle est rare, et il existait un doute sur son déclin possible. Elle fait aussi partie de la liste des espèces prioritaires dans le cadre du Plan Saint-Laurent Vision 2000.

Les principaux documents sur lesquels se base le présent rapport sur la situation du brochet d'Amérique sont le mémoire de maîtrise de M^{me} Michèle Lapointe (1980), les inventaires ichtyologiques effectués, depuis le début des années

1960, par le Service de l'aménagement et de l'exploitation de la faune du ministère de l'Environnement et de la Faune des régions de Montréal, de l'Estrie et de Trois-Rivières, ainsi que sur les informations contenues dans l'ouvrage de Scott et Crossman (1974).

Classification et nomenclature

Le brochet d'Amérique appartient à la famille des Ésocidés qui ne comprend qu'un seul genre, *Esox*. Au Canada il n'existe que quatre espèces de brochets, le grand brochet, *Esox lucius*, le maskinongé, *E. masquinongy*, le brochet maillé, *E. niger*, et enfin *E. americanus*, qui présente deux sous-espèces, soit le brochet d'Amérique, *E. americanus americanus*, et le brochet vermiculé, *E. americanus vermiculatus* (Scott et Crossman 1974). Historiquement, le brochet d'Amérique a été considéré tour à tour comme une espèce distincte du brochet vermiculé, et comme la forme typique dont le brochet vermiculé est une sous-espèce. Aujourd'hui, les deux formes sont con-

*Reviewed and approved by COSEWIC April 1998., status assigned — Not At Risk.

sidérées comme des sous-espèces (Scott et Crossman 1974). Les populations du sud des États-unis seraient intermédiaires entre les deux sous-espèces, c'est-à-dire qu'il y a hybridation (Reist et Crossman 1987; Scott et Crossman 1974; Crossman 1966). Il peut aussi y avoir hybridation avec le brochet maillé et le grand brochet, mais dans ce dernier cas les hybrides sont stériles (Scott et Crossman 1974).

Le nom de brochet des marais est parfois utilisé pour désigner le brochet d'Amérique (Mongeau et al. 1974). Le nom anglais de ce poisson, Red-finned Pickerel, fait référence à sa taille, pickerel signifiant petit brochet « little pike » et à la couleur rouge-orangée de ses nageoires inférieures (Scott et Crossman 1974).

Le brochet d'Amérique est arrivé récemment au Canada. La première mention date de 1944 (Cuerrier 1947). Il semble qu'il aurait pénétré en eaux canadiennes par la voie de communication artificielle construite en 1819 entre la rivière Hudson et le régime du lac Champlain-rivière Richelieu (Scott et Crossman 1974).

Description

Les informations suivantes sont tirées de Scott et Crossman (1974). Le brochet d'Amérique présente un corps de forme allongée, plutôt cylindrique, et aplati dorsalement devant la nageoire dorsale. Les adultes dépassent rarement la longueur de 300 mm (Figure 1). La tête est modérément longue, plate, nue sur le dessus et large. Les joues et les opercules sont entièrement recouverts d'écailles. Le museau est court, large et convexe entre l'oeil et le bout. La bouche est grande et horizontale, et la mâchoire inférieure est légèrement plus longue que le museau. Les nageoires sont arrondies. Il n'y a qu'une seule nageoire dorsale, à rayons mous, placée loin derrière. La nageoire caudale est fourchue. La nageoire anale est placée juste sous la nageoire dorsale. Les nageoires pelviennes sont abdominales, au centre du corps. Enfin, les nageoires pectorales sont placées sous le volet operculaire. Les nageoires inférieures; pectorales, pelviennes

et anale présentent une couleur allant du rouge à l'orange.

Les brochetons d'une longueur de 50 mm présentent une coloration plutôt uniforme d'un brun foncé. À partir de 100 mm de longueur, les prolongements verticaux d'une bande latérale pâle commencent à séparer les flancs en barres verticales sombres. Le patron de coloration des adultes fait son apparition alors que le brochet atteint une taille entre 100 mm et 150 mm. Alors la face dorsale du corps et de la tête, ainsi que la partie supérieure des flancs vont du brun pâle au vert olive. Il existe une faible bande pâle sur le milieu du dos, de la nuque à l'origine de la nageoire dorsale. Les flancs sont marqués de 20 à 36 barres verticales ondulées, allant du vert olive au brun foncé. Les espaces clairs entre les barres sont plus étroits que celles-ci. La face ventrale du brochet varie de l'ambre pâle au blanc laiteux. La tête est marquée de deux barres noires, l'une sous-orbitaire, l'autre postorbitaire. La surface inférieure du mandibule est pigmentée et ce, de façon plus importante chez les femelles. La pupille de l'oeil varie du jaune au vert.

Le brochet d'Amérique se distingue du grand brochet et du maskinongé, par un moins grand nombre de pores sous-mandibulaires (ordinairement 7 ou 8). Il présente moins de rayons branchiostèges que le brochet maillé, 11 à 13 contre 14 à 17. Enfin, on le sépare de la sous-espèce du brochet vermiculé, par son museau court à profil supérieur convexe, un plus grand nombre d'écailles cardioïdes entre les nageoires pelviennes (plus de 5) et la coloration rouge-orangée de ses nageoires inférieures.

Répartition

Répartition générale

La Figure 2 présente la distribution nord-américaine des deux sous-espèces de *Esox americanus*. On remarque que les deux sous-espèces sont largement répandues aux États-Unis. On les rencontre dans les eaux douces de la plaine côtière atlantique jusqu'au lac Okeechobee en Floride, dans les tributaires du golfe du Mexique jusqu'à la rivière Brazos au Texas



FIGURE 1. Brochet d'Amérique, *Esox americanus americanus*, Male 190 mm; Québec, rivière Godefroy (A. Odum d'après Scott et Crossman 1975 avec permission).

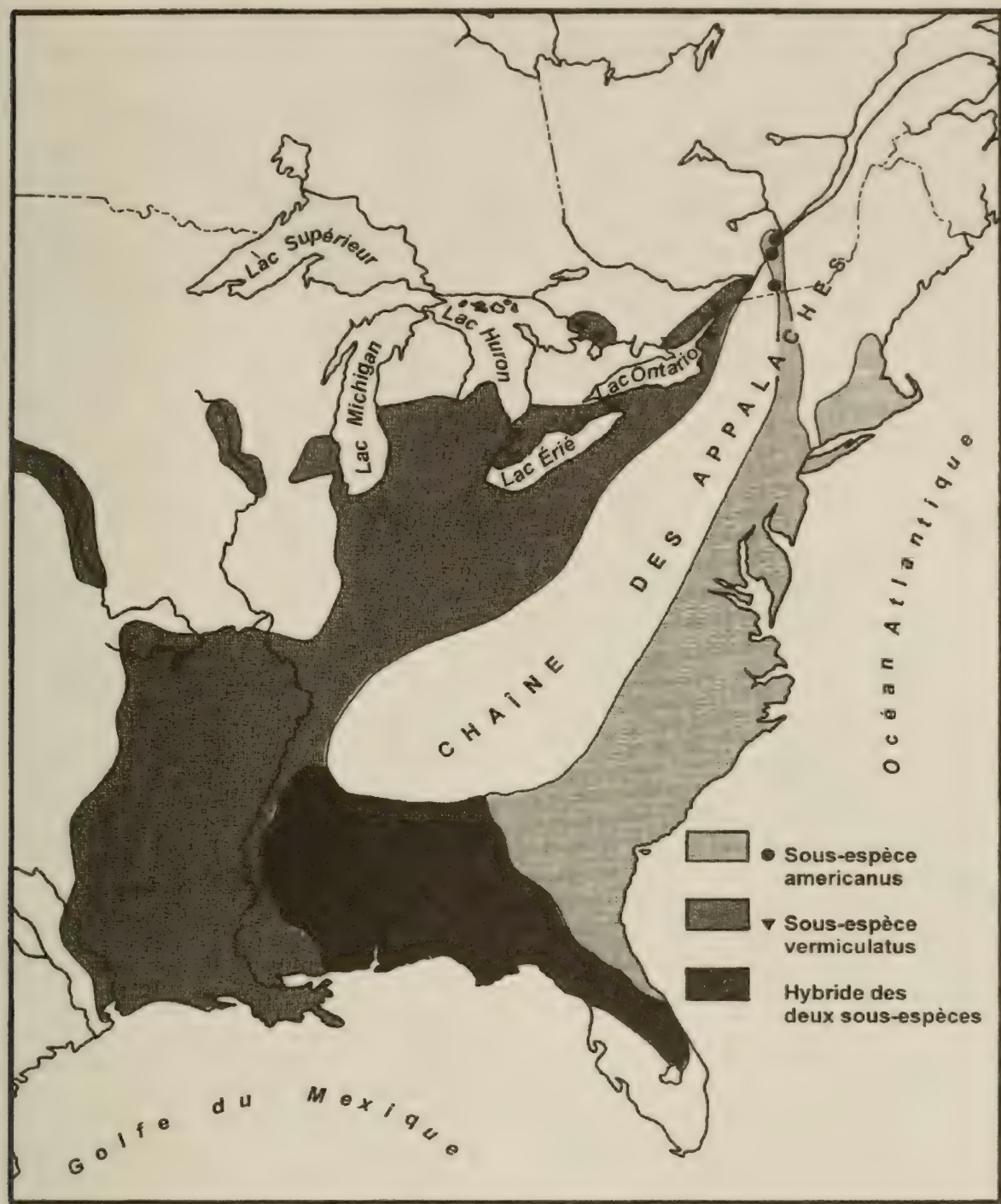


FIGURE 2. Aire de répartition mondiale des deux sous-espèces d*Esox americanus* modifiée d'après Crossman 1966 (tirée de Lapointe 1980).

à l'ouest et dans le Mississippi et ses tributaires. Les sous-espèces sont séparées par la chaîne de montagnes des Appalaches, le brochet d'Amérique occupant l'est et le brochet vermiculé occupant l'ouest, sauf au sud où elles s'hybrident. On remarque, de plus, que la limite septentrionale de la répartition géographique des deux sous-espèces est le système des Grands Lacs inférieurs et le fleuve Saint-Laurent et quelques-uns de ses tributaires.

Répartition au Canada

Le brochet d'Amérique au Canada est limité au Québec. Sa répartition (Figure 3) comprend le fleuve

Saint-Laurent depuis les îles de Contrecoeur jusqu'à l'embouchure de la rivière Godefroy, y compris le lac Saint-Pierre et plus particulièrement la région autour des îles de Berthier; le bassin de la rivière Richelieu, y compris le lac Champlain, la Baie Missisquoi et la rivière du Sud; ainsi que les rivières Yamaska, Saint-François, Maskinongé et Godefroy, y compris le lac Saint-Paul (Mongeau et al. 1974; Scott et Crossman 1974; Massé et Mongeau 1974; Mongeau 1979 a et b; Mongeau et al. 1981; Dubé 1986; Dubé et al. 1988; P.N. Mellado, étudiant à la maîtrise au département de biologie de l'Université

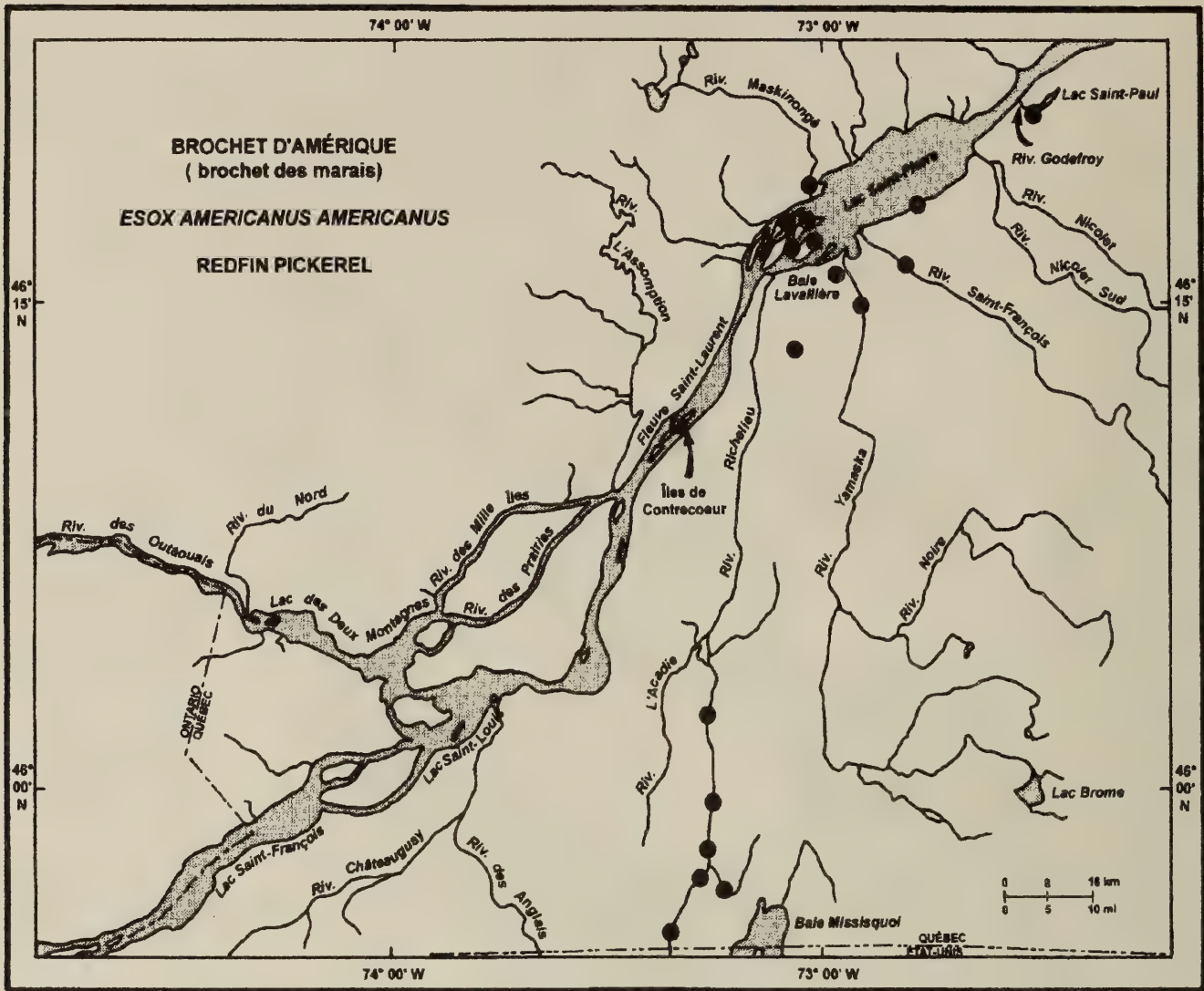


FIGURE 3. Aire de répartition du brochet d'Amérique, *Exos americanus americanus*, au Canada d'après les sites de capture (modifiée de Mongeau et al. 1974).

du Québec à Montréal, Montréal, QC; communication personnelle.). Il s'agit de la répartition minimale inventoriée, puisque le brochet d'Amérique échappe souvent aux engins de pêche couramment utilisés lors des inventaires ichtyologiques. De plus, l'habitude qu'il a de se tenir dans les herbiers denses complique sa capture.

Enfin, il n'a pas fait l'objet d'étude de répartition spécifique. Il est à noter que la mention de l'espèce dans les îles de Contrecoeur est récente (1994; Mellado 1996) et que c'est la première fois que les brochets ont été inventoriés si loin en amont de l'embouchure de la rivière Richelieu. Il y aurait donc une certaine extension de l'aire de répartition vers l'ouest. Ceci engendre la possibilité de recoupement avec l'aire de répartition de l'autre sous-espèce, le brochet vermiculé, dont l'extrémité est de l'aire de répartition se trouve autour de l'île Perrot.

Biologie et écologie

Biologie générale

La biologie du brochet d'Amérique au Canada est

peu connue. Les renseignements suivants ont été tirés de l'oeuvre de Scott et Crossman (1974), de l'étude de Crossman (1962) en Caroline du Nord, ainsi que de celles de Dubé et al. (1988) et de Lapointe (1980) dans le Haut-Richelieu, Québec. Cette dernière étude faisait le point sur les connaissances acquises à cette époque et la revue informatisée de la littérature de 1978 à 1995, effectuée dans le cadre du présent rapport de statut, n'a ajouté que quelques informations supplémentaires. Afin de compléter le portrait général brossé ci-dessous, des données sur la croissance en longueur et en poids, sur l'alimentation, et sur le rapport gonado-somatique des brochets d'Amérique du Haut-Richelieu sont présentées en Figures 4-6.

Le brochet d'Amérique fraie généralement au printemps, mais une fraie automnale est possible comme chez les autres Ésocidés. Il n'y a pas eu d'observation de la fraie du brochet d'Amérique au Canada, mais on a retrouvé des oeufs aux mêmes endroits et au même moment que ceux pondus par le grand brochet. La période et les aires de fraie

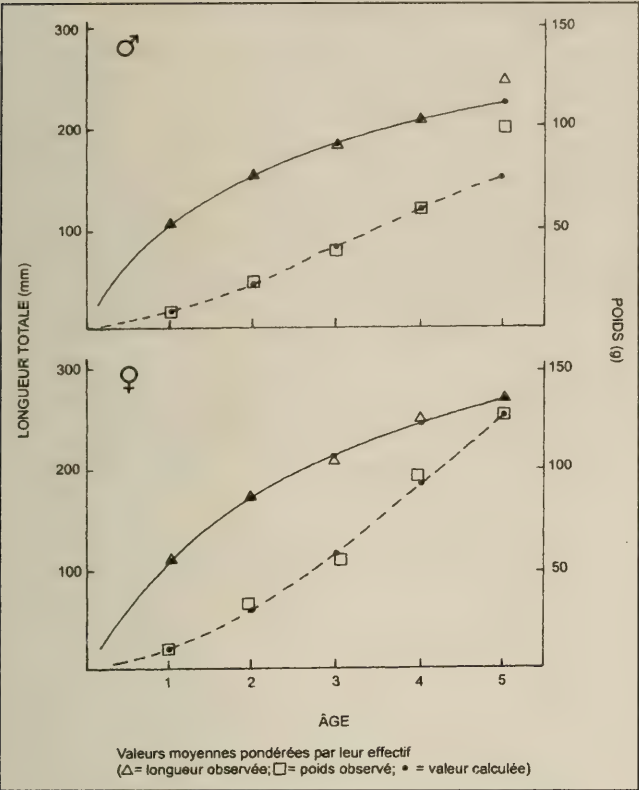


FIGURE 4. Courbes de croissance en longueur (-) et en poids (- -) des brochets d'Amérique mâles et femelles calculées d'après le modèle de von Bertalanffy pour le Haut-Richelieu (tiré de Lapointe 1980).

seraient donc probablement les mêmes que celles du grand brochet.

Typiquement, au printemps, la fraie débute en période d'inondation des rives, alors que la température de l'eau atteint 10°C. La durée de la fraie serait d'environ deux semaines (Scott et Crossman 1974). La fraie aurait lieu près des rives inondées couvertes de végétation en eau peu profonde. Des données récoltées par Dubé et al. (1988) indiquent à cet effet que la répartition des œufs était équivalente entre les zones à plus de 60 cm de profondeur et celles à moins de 60 cm (Lapointe 1980). La prairie humide à phalaris, et le marais à scirpe et à typha, seraient caractéristiques de l'habitat de fraie. Les œufs sont pondus au hasard et abandonnés sur le fond et sur la végétation où ils adhèrent.

Le nombre total moyen d'œufs est de 3716, dont 186 à 542 sont mûrs, c'est-à-dire prêts à être pondus. Le nombre total d'œufs dans un brochet d'Amérique est environ un tiers du nombre total contenu dans un brochet vermiculé de même taille. La fécondité du brochet d'Amérique serait donc moindre que celle du brochet vermiculé. En tout temps, avant la fraie, il y a, en plus des œufs mûrs, des œufs à deux autres stades de recrutement. Selon des découvertes récentes, il semble que ces autres œufs, qui ne sont pas expulsés lors de la fraie printanière, pourraient mûrir au cours de l'été et servir à une fraie autom-

nale, sinon il y aurait atrésie (E. J. Crossman, Curator Emeritus, Royal Ontario Museum, Toronto, Ontario; communication personnelle). De fait, des larves d'Esocidés portant encore des vestiges de la resicule utelline, ont été capturées aux mois d'octobre et de novembre 1996 au marais de l'île St-Eugène. Ces larves ont été identifiées comme étant des brochets de Amérique de taille allant de 14 à 32 mm ce qui suggère fortement une reproduction à la fin de l'été ou au début de l'automne (Letendre et Dumas 1999). Les œufs mûrs sont transparents, de couleur jaune doré, et présentent un diamètre moyen de 1,9 mm. Les œufs éclosent après une période de 10 à 14 jours, et les alevins demeurent inactifs pendant le période de résorption de la réserve vitelline, soit de 10 à 12 jours. Par après ils commencent à se nourrir activement.

À la sortie de l'œuf, les alevins mesurent de 5,8 à 6,1 mm. La croissance est très rapide le premier été, et peut atteindre de 20 à 30 mm par mois. Dans le Haut-Richelieu, les jeunes de l'année atteignent une taille moyenne d'un peu plus de 100 mm à la fin de septembre. Par la suite, la croissance diffère selon le sexe. Les femelles croissent plus vite et plus longtemps que les mâles. Les longueurs rétrocalculées aux différents annuli pour les femelles d'âge 1, 2, 3, 4, et 5 sont respectivement de 106–120 mm, de 163–179 mm, de 202–220 mm, de 244–247 mm et de 269 mm. Pour les mâles ces longueurs sont de 99–110 mm, de 141–156 mm, de 182–193 mm, de

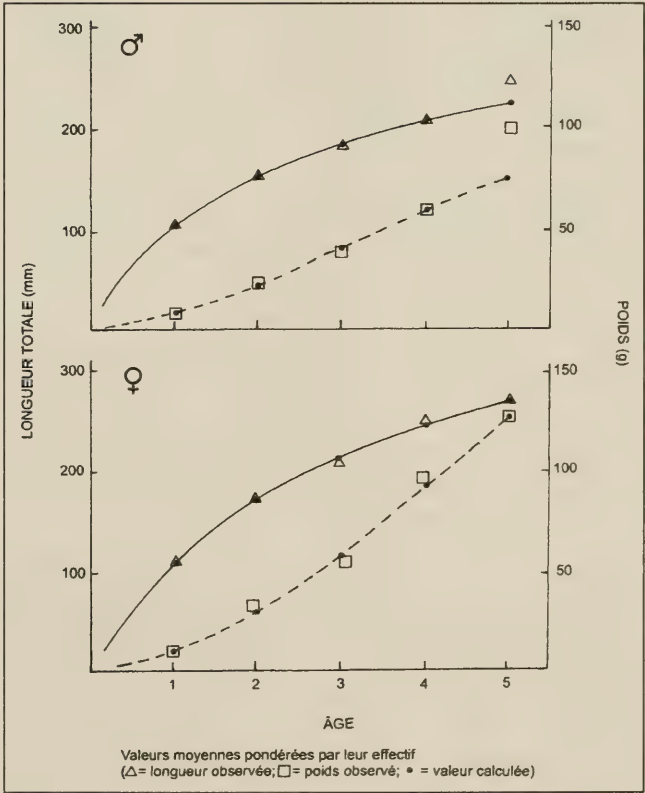


FIGURE 5. Croissance des jeunes brochets d'Amérique de l'année capturés dans le Haut-Richelieu en 1976.

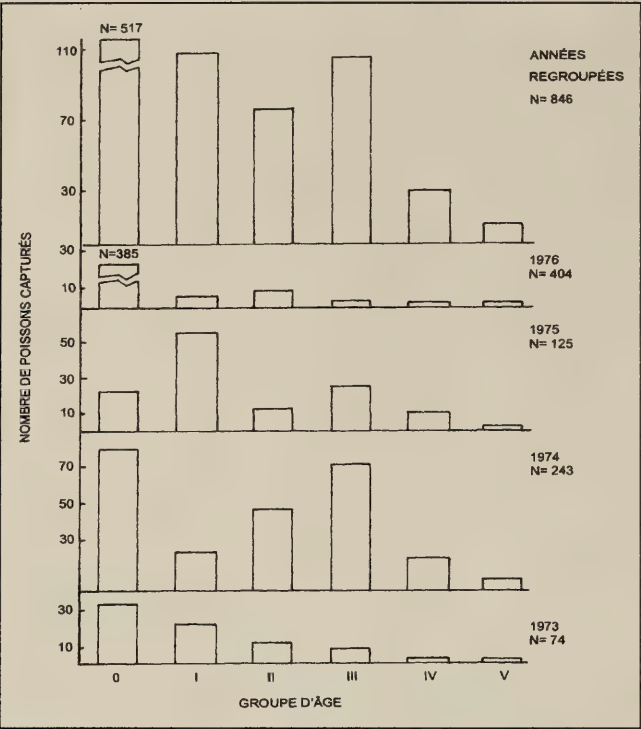


FIGURE 6. Âge des spécimens capturés à chaque année d'échantillonnage dans le haut-Richelieu (tiré de Lapointe 1980).

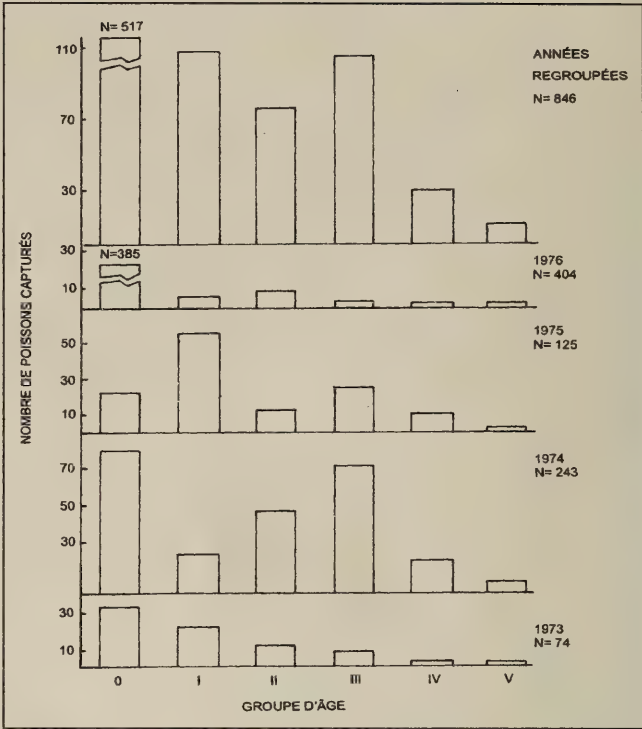


FIGURE 7. Végétation des terres humides au lac Saint-Pierre (MLCP 1986). Rapport Sur La Situation Du Brochet D'amérique (*Esox americanus americanus*), Au Canada*

204–228 et de 244 mm respectivement (Lapointe 1980).

Le taux de croissance du brochet d'Amérique du Haut-Richelieu est très semblable à celui noté pour la sous-espèce en Caroline du Nord, soit à 10° de latitude plus au sud (Lapointe 1980). Des mesures sommaires relevées sur les brochets d'Amérique de la baie Lavallière confirment ce rythme de croissance (Lepage et Gélinas 1996). Aucune mention de l'âge ou de la taille à maturité sexuelle n'a été relevée dans les informations disponibles pour le brochet d'Amérique. On sait par contre, que le brochet vermiculé devient mature lorsqu'il atteint 157 mm chez les femelles et 141 mm chez les mâles, soit vers l'âge de deux ans. Il est plausible que ce soit le cas pour le brochet d'Amérique, étant donné un rythme de croissance similaire (Lapointe 1980). Les femelles semblent vivre plus longtemps, et l'âge maximal atteint par les brochets d'Amérique serait de 7 ans. Dans le Haut-Richelieu, les individus capturés les plus âgés atteignaient 5 ans.

Les brochets d'Amérique sont des poissons omnivores se nourrissant principalement de crustacés, de mollusques, d'insectes, de poissons et d'amphibiens (Lapointe 1980). Bien qu'on puisse retrouver des proies de toutes catégories chez des individus de toutes les tailles, il existe cependant des différences quant à la proportion des différents groupes de proies utilisés selon la taille du brochet. Ainsi les jeunes individus de moins de 100 mm consomment une grande proportion de crustacés (cladocères, ostra-

codes, amphipodes et isopodes) et dans une moindre mesure de larves d'insectes aquatiques tels les éphéméroptères, les diptères, les hémiptères et les odonates (Lapointe 1980). Chez les brochets de 100 à 150 mm, les crustacés demeurent une part importante du régime, mais les insectes au printemps, et les poissons en été et en automne deviennent omniprésents dans le régime alimentaire. À partir de la taille de 150 mm, le poisson devient l'élément le plus important du régime des brochets d'Amérique bien que les autres éléments soient aussi présents. Les espèces de poissons consommées par les brochets d'Amérique sont nombreuses et se regroupent dans les familles suivantes : Centrarchidés, Cyprinidés, Ésocidés, Percidés, Ictaluridés, Cyprinodontidés et Umbridés. Il peut y avoir du cannibalisme.

Le brochet d'Amérique étant une espèce plutôt discrète et peu étudiée, il n'existe pas de données sur son comportement. Il semble par contre, selon les patrons de captures, que ce soit un poisson plutôt sédentaire, se déplaçant très peu. On sait que les brochetons demeurent à proximité des aires d'alevinage jusqu'à la fin de l'été (Lapointe 1980). Comme on l'a vu, il est un prédateur de plusieurs espèces de poissons, mais il peut aussi servir de proie. Son alimentation omnivore le met en situation de compétition potentielle avec un grand nombre d'espèces ichtyologiques. Les jeunes entrent en concurrence avec les espèces qui consomment des invertébrés (Scott et Crossman 1974). Par contre, il est probable-

ment la proie d'autres espèces telles que les crapets, la perchaude, la barbotte brune, la barbus de rivière et les autres brochets qui partagent son habitat.

De ce résumé de la biologie du brochet d'Amérique, on retient que ce poisson présente une faible fécondité, a un cycle de vie court, entretient des relations de compétition potentielles avec plusieurs espèces, et est tour à tour une proie et un prédateur. Ces facteurs peuvent contribuer à limiter son abondance.

Habitat

L'habitat typique du brochet d'Amérique, tant des adultes que des juvéniles, et ce, tout au long de leur cycle vital, se trouve dans les cours d'eau ordinairement acides, à eaux mortes et à végétation dense. On peut aussi le retrouver dans des étangs, des eaux de retenue riche en végétation et les baies tranquilles des grands lacs et rivières.

Lapointe (1980) décrit l'habitat dans lequel on retrouve le brochet d'Amérique dans le Haut-Richelieu. Il s'agit de ruisseaux, de canaux artificiels ou de petites baies de faible profondeur, alimentés par les eaux de ruissellement des terres agricoles. Tous sont caractérisés par des eaux peu profondes, plutôt riches, et quelque peu turbides, et les courants y sont faibles ou nuls. La végétation aquatique y est très abondante et composée de plantes aquatiques submergées, telles *Myriophyllum exalbescens*, *Elodea canadensis*, et *Potamogeton* spp., ainsi que de plantes aquatiques à feuillage flottant, telles *Nuphar variegatum* ou *rubrodiscum* et *Nymphaea tuberosa*. La température de l'eau peut atteindre 26°C, et le pH serait de 8,4. Cette description de l'habitat du brochet d'Amérique dans le Haut-Richelieu correspond assez bien à celle faite pour la sous-espèce en Caroline du Nord, à l'exception du fait que les cours d'eau en question aux États-Unis sont alimentés par des marécages dont les eaux à forte teneur en matière humique présentent du pH acide, soit de 4,2 à 4,9 (Crossman 1962).

Dans le fleuve Saint-Laurent, l'archipel du lac Saint-Pierre est la zone la plus utilisée par le brochet d'Amérique selon Massé et Mongeau (1974). Elle est caractérisée par la présence d'herbiers aquatiques et de marais de faible et de grande profondeur (Figure 7). Les canaux entre les différentes îles de l'archipel sont les lieux où on le capture le plus fréquemment. Dans le fleuve Saint-Laurent, le pH de l'eau est aussi généralement alcalin. L'acidité de l'eau ne semble donc pas être une caractéristique essentielle de l'habitat du brochet d'Amérique.

L'étude de Dubé et al. (1988) à l'île Sainte-Marie dans le Richelieu décrit le milieu de fraie du brochet d'Amérique. Il s'agit de prairie humide à phalaris et de marais à scirpe et à typha, à des profondeurs variant de 32 à 95 cm.

Le brochet vermiculé et le brochet d'Amérique, tolèrent et même préfèrent des températures élevées.

Ils peuvent aussi tolérer de très faibles concentrations en oxygène (0,3 ppm) caractéristiques des eaux très chaudes (Scott et Crossman 1974). Par contre, les milieux où l'oxygénation est faible à cause d'une forte pollution organique ne sont pas habités par les brochets (E. J. Crossman, communication personnelle). Il semblerait que les jeunes de l'année et les adultes partagent tous le même habitat puisqu'ils ont été capturés aux mêmes endroits lors des inventaires récents dans la baie Lavallière (Lepage et Gélinas 1996).

Dynamique des populations

Il existe très peu de données concernant l'abondance passée ou présente du brochet d'Amérique. Cependant, il semble que la fertilité de l'espèce soit faible (Scott et Crossman 1974). La fécondité du brochet d'Amérique serait moindre que celle du brochet vermiculé : le nombre total d'œufs dans un brochet d'Amérique est d'environ le tiers du nombre total contenu dans un brochet vermiculé de même taille (Scott et Crossman 1974). Par ailleurs, le succès de la reproduction est probablement fonction de la durée et du niveau des inondations, tout comme c'est le cas pour le grand brochet (Machniak 1975; Massé et al. 1988).

Facteurs limitatifs

Compte tenu que le brochet d'Amérique présente une faible fertilité (Scott et Crossman 1974), est peu mobile (Lapointe 1980), exige un habitat caractérisé par des herbiers très dense qui sont des milieux souvent perturbés et que le Québec soit à la limite septentrionale de sa répartition géographique, il semble peu probable que l'espèce puisse prendre beaucoup d'expansion dans l'avenir.

Par contre, la survie des populations est possible par le maintien de l'habitat. L'assèchement des herbiers et le contrôle des inondations printanières sur les terres agricoles peuvent s'avérer fatals pour la survie des adultes, des œufs et des alevins.

Outre les modifications physiques de l'habitat et la pollution organique, il est difficile de préciser quels autres facteurs sont limitatifs pour le brochet d'Amérique, les éléments réglant la dynamique des populations de cette sous-espèce n'ayant pas été étudiés. Il est par contre permis de croire que la prédation et la compétition pourraient jouer un rôle dans l'expansion limitée du brochet d'Amérique.

Adaptabilité

Il existe peu d'information concernant l'adaptabilité de l'espèce, par exemple, aux changements dans les conditions du milieu. Bien que ce ne soit pas documenté, il semble peu probable que le brochet d'Amérique soit une sous-espèce très flexible au niveau de ses exigences d'habitat, puisqu'il n'a pas pris d'expansion importante au Québec depuis 50 ans. Un exemple inverse, serait celui de l'éperlan arc-en-ciel (*Osmerus mordax*) qui a envahi le lac

Ontario de façon impressionnante sur une période de 15 ans (Christie 1972). Les températures froides des eaux du Québec, ainsi que les grandes étendues d'eau claire, sans herbiers importants, ne sont pas propices à l'expansion de cette sous-espèce. De plus, la grande détérioration des herbiers aquatiques autour des îles près de Montréal depuis la deuxième moitié de ce siècle n'aura sans doute pas aidé à l'extension de l'aire de répartition du brochet d'Amérique vers l'ouest.

Aujourd'hui, avec les divers programmes visant la restauration et la dépollution des milieux humides (par exemple le Plan Saint-Laurent Vison 2000 et le Plan d'intervention de Montréal), la sous-espèce pourra vraisemblablement étendre son aire dans cette direction. Dans ce cas, le brochet d'Amérique se retrouvera sur le même territoire que le brochet vermiculé au Québec. L'extrémité est de l'aire de répartition se situe à l'île Perrot, et il pourra y avoir hybridation comme dans le sud des États-Unis.

Importance particulière

Le brochet d'Amérique, bien qu'il puisse présenter une certaine abondance localement, n'est pas un poisson d'importance pour la pêche commerciale, sportive ou de subsistance au Québec. C'est une sous-espèce qui n'est pas très connue auprès du grand public, qui la confond souvent avec des jeunes grands brochets et la remet à l'eau ou la jette. Aux États-Unis, elle fait l'objet d'une pêche sportive (Scott et Crossman 1974).

L'impact de l'avènement du brochet d'Amérique, au niveau de la chaîne trophique, est inconnu. Il est probable qu'il joue un rôle similaire à celui du grand brochet, en utilisant des proies de moins grande taille.

À en juger par la faible quantité d'informations disponibles à son sujet, il ne semble pas attirer l'intérêt des milieux scientifiques québécois, canadiens et américains. Vu sa faible abondance et sa répartition restreinte, il ne présente pas d'intérêt comme bio-indicateur, les espèces utilisées à cet effet devant présenter une large répartition et une abondance élevée.

Son arrivée récente au Canada, et le faible intérêt du public pour cette sous-espèce méconnue, ne font pas du brochet d'Amérique un poisson d'importance culturelle ou sociale.

Le brochet d'Amérique est donc peu connu et de peu d'intérêt pour le grand public, contrairement au grand brochet et au maskinongé qui sont extrêmement populaires comme espèce d'intérêt sportif. À cet égard, son importance est semblable à celle de l'autre sous-espèce, soit le brochet vermiculé. L'importance du brochet d'Amérique réside en sa rareté, son adaptation aux milieux humides et aux petits cours d'eau, en son caractère énigmatique, en sa beauté et en son apport au patrimoine faunique du Québec.

Bilan de la situation

État des populations

Il n'existe que très peu de données concernant l'abondance passée ou présente du brochet d'Amérique au Québec. Son aire de répartition a été établie à partir de mentions de captures, et très souvent il s'agissait de la capture d'un seul individu. Les populations les plus abondantes se retrouveraient dans l'archipel du lac Saint-Pierre.

Dans le Haut-Richelieu, la population semble stable depuis une quarantaine d'années (R. Fortin, J. Dubé et P. Gosselin, communication personnelle). Scott et Crossman (1974) mentionnent que l'abondance de l'espèce dans le fleuve Saint-Laurent à la hauteur du lac Saint-Pierre aurait diminué suite à l'aménagement de la voie maritime du Saint-Laurent. Un inventaire auprès des pêcheurs commerciaux utilisant des verveux au lac Saint-Pierre en 1983 a révélé que le brochet d'Amérique formait moins de 0,1% de la biomasse annuelle capturée, soit environ 53 kg (Roy 1985, 1986). Les captures, à cette époque, étaient concentrées dans l'archipel du lac Saint-Pierre et dans la baie de Maskinongé. Les captures, qui sont accidentelles puisque les espèces visées par ces pêcheurs sont surtout la perchaude et la barbotte, étaient plus fréquentes en avril et mai (Roy 1985, 1986). Des entrevues téléphoniques avec trois pêcheurs actifs ayant au minimum 20 ans d'expérience dans le secteur, ont confirmé que les captures sont rares (moins de cinq par année) et se font plutôt au printemps (R. Michaud, J. Michaud, J.-C. Adant, communication personnelle). Ces personnes semblent d'accord pour dire que l'abondance est légèrement plus élevée depuis cinq ou six ans.

À ce jour, il est impossible de statuer de façon rigoureuse sur l'état des populations du brochet d'Amérique. Il semblerait que les seuls endroits où il soit modérément abondant soient l'archipel du lac Saint-Pierre et le Haut-Richelieu. À ces endroits, les populations seraient stables. Par contre, des inventaires récents ont permis d'établir qu'il existe dans la baie Lavallière et dans le marais Saint-Eugène, des populations indépendantes qui s'y reproduisent. D'après les indications, l'abondance du brochet d'Amérique dans la baie Lavallière serait environ 5 à 6 fois inférieure à celle du grand brochet (Lepage et Gélinas 1996). Ailleurs, les captures ne sont qu'occasionnelles et peu nombreuses. Bien qu'il soit probable que le nombre de brochets d'Amérique soit faible, il existe aussi un biais dans l'évaluation de son abondance, causé par les méthodes et les lieux d'échantillonnage qui ne visent pas cette sous-espèce.

Menaces à la survie de l'espèce

Avec le peu de connaissances disponibles sur le brochet d'Amérique, il est difficile d'établir les menaces à sa survie. Par contre, les caractéristiques de son habitat préférentiel étant assez bien cernées, il est possible d'affirmer que l'assèchement des herbiers et

l'endiguement pour empêcher l'inondation printanière des terres agricoles sont des menaces à sa survie, ainsi qu'à celle de nombreuses autres espèces. Il est à noter que de tels ouvrages ont déjà été effectués dans le Haut-Richelieu là où le brochet d'Amérique est abondant (Dubé 1986). En ce moment, aucun projet potentiellement dangereux pour le brochet n'est à l'étude que ce soit dans le Haut-Richelieu ou dans l'archipel du lac Saint-Pierre.

Certains aménagements fauniques visant la sauvagine entraînent la formation de petits plans d'eau isolés là où il y avait avant communication entre les marais et l'eau libre. Ces aménagements devraient tenir compte des exigences du brochet d'Amérique lorsqu'il est présent, c'est-à-dire permettre la libre circulation des poissons, favoriser la présence des herbiers aquatiques et permettre l'inondation de la prairie humide au printemps, pour des profondeurs entre 30 et 90 cm.

La pollution est une menace pour toutes les espèces vivantes et donc pour le brochet d'Amérique. À ce niveau, il semble que la pollution diffuse originant des pratiques agricoles intensives lui soit particulièrement néfaste.

Sur le plan des facteurs naturels comme la maladie, la prédation ou la compétition, peu d'informations sont disponibles. Par contre, il semble que le brochet d'Amérique ait trouvé une niche dans la chaîne trophique qu'il est en mesure de conserver dans les milieux où il est plus abondant et où les populations se maintiennent depuis plusieurs années.

Protection légale et mesures de conservation

Le brochet d'Amérique n'est pas mentionné spécifiquement dans les règlements québécois de pêche sportive, mais est groupé avec les autres Ésoïdés sous l'appellation de brochets. On le retrouve dans les zones de pêche sportive 5, 6, 7 et 8 du Québec. La saison de pêche aux brochets est fermée au printemps afin de protéger les poissons en période de reproduction. Partout, la limite de prise quotidienne est de six, toutes espèces confondues (MEF 1995).

Il est défendu de pêcher le brochet d'Amérique commercialement ou de l'utiliser comme poisson-appât. Par contre, les individus capturés à la pêche sportive peuvent être vendus. Cependant, les probabilités de capture sont extrêmement faibles.

Pour ce qui est de la protection de son habitat, il y a un site protégé sur son aire de répartition, soit la réserve écologique Marcel-Raymond dans le Haut-Richelieu (Hone 1988). De plus, le MEF est présentement en cours de procédures pour donner à un secteur du lac Saint-Paul le statut de réserve écologique (réserve écologique projetée Léon-Provancher) (G. St-Onge, communication personnelle).

La Loi sur la conservation et la mise en valeur de la faune protège l'habitat du poisson sur les terres publiques du Québec. Aux fins législatives, l'habitat

du poisson inclut les cours d'eau, les marais et les marécages où l'on retrouve du poisson jusqu'à la cote de récurrence d'inondation de 2 ans, ou, si celle-ci n'est pas disponible, jusqu'à la ligne naturelle des hautes eaux. Entre autres, le terme poisson comprend en plus des poissons eux-mêmes, leurs produits sexuels et leurs oeufs de même que les crustacés et les mollusques. Certaines interventions sont interdites dans cet habitat alors que d'autres peuvent être réalisées conformément au Règlement sur les habitats fauniques.

La Loi sur les pêches du gouvernement fédéral protège aussi l'habitat du poisson qu'elle définit comme les frayères, les aires d'alevinage, les aires d'alimentation et les voies de migration dont dépend, directement ou indirectement, la survie des poissons (article 34). L'esprit de cette loi est d'interdire l'exploitation d'ouvrages ou d'entreprises qui entraînent la détérioration, la destruction ou la perturbation de l'habitat du poisson (article 35[1]), à moins que ces activités ne soient autorisées par le ministre des Pêches et des Océans ou faites conformément aux règlements (article 35[2]).

Enfin, tout aménagement visant à améliorer ou à agrandir les herbiers et à permettre l'inondation des basses terres lors des crues printanières, sur l'aire de répartition de cette sous-espèce, devrait aider à maintenir sinon augmenter les populations de brochets d'Amérique.

Statuts actuels, légaux ou autres

À ce stade, outre le fait que le brochet d'Amérique ait été placé sur la liste des espèces susceptibles d'être désignées menacées ou vulnérables par le ministère de l'Environnement et de la Faune du Québec (Beaulieu 1992), et sur la liste des espèces prioritaires du Plan d'action Saint-Laurent, aucun statut légal n'a été accordé à cette sous-espèce, que ce soit au niveau international, national ou provincial. Le présent document vise cet objectif au niveau provincial et national.

Conclusion/évaluation

Le présent rapport a mis en lumière plusieurs faits importants concernant le brochet d'Amérique. Lorsque l'on considère cette sous-espèce, il est essentiel de tenir compte des éléments suivants :

il existe très peu d'informations au sujet du brochet d'Amérique au Québec outre certains travaux réalisés dans le Haut-Richelieu, les informations contenues dans Scott et Crossman (1974) et les résultats des inventaires ichtyologiques effectués au cours des 50 dernières années dans le cadre de diverses études;

l'aire de répartition du brochet d'Amérique au Canada n'inclut que le Québec;

la sous-espèce est à l'extrémité nord de son aire de répartition mondiale;

l'aire de répartition au Québec est restreinte au secteur du fleuve Saint-Laurent entre les îles de Contrecoeur et l'embouchure de la rivière Godefroy, ainsi qu'aux

réseaux hydrographiques des rivières Richelieu (incluant le lac Champlain), Godefroy (incluant le lac saint-Paul), Yamaska et Saint-François;

l'abondance de la sous-espèce semble faible en général, trois populations bien établies étant connues, soit celles du Haut-Richelieu, de l'archipel du lac Saint-Pierre et de la baie Lavallière;

l'abondance de la sous-espèce est possiblement sous-estimée puisque très peu d'études lui ont été consacrées et que les inventaires ichthyologiques classiques ne font pas appel à des méthodes propices à sa capture;

l'habitat du brochet d'Amérique, tant au niveau des juvéniles que des adultes, est caractérisé par des eaux propres, des herbiers denses de faible profondeur et des températures estivales élevées;

les aires de fraie seraient identiques à celles du grand brochet, soit la zone riparienne inondée, ce qui rend la sous-espèce sensible aux travaux de remblaiement, d'endiguement ou d'assèchement;

outre son apport au patrimoine faunique québécois et sa valeur intrinsèque en tant qu'élément de la biodiversité, le brochet d'Amérique n'a pas de valeur économique, culturelle ou sociale; il est très peu connu du grand public;

cette sous-espèce ne jouit d'aucune protection légale particulière.

Ainsi le brochet d'Amérique est un poisson plutôt rare, à propos duquel peu de choses sont connues et qui est très sensible aux modifications qui peuvent être apportées à son habitat. La conservation de cette sous-espèce passe par la protection de son habitat, par l'acquisition de connaissances supplémentaires à son sujet et par la sensibilisation du grand public à son existence, ainsi qu'à sa valeur intrinsèque, écologique et esthétique.

Au Canada, la sous-espèce le brochet d'Amérique ne présente pas une grande aire de répartition, est à la limite septentrionale de son aire de répartition, et est généralement peu abondante. Il s'agit en fait d'un poisson rare. Les seules populations d'importance se trouvent dans l'archipel du lac Saint-Pierre et dans le Haut-Richelieu, et où il semble que l'abondance soit stable. Le brochet d'Amérique n'a pas d'importance économique, mais sa beauté et sa rareté en font un membre important du patrimoine faunique canadien. Bien qu'on ait peu de connaissances sur le brochet d'Amérique, il est plutôt évident que les menaces à son habitat que sont les endiguements et les assèchements d'herbiers aquatiques, peuvent être déterminants pour la survie de la sous-espèce.

La protection de son habitat, plus particulièrement de ses aires de fraie et d'alevinage, sera déterminante pour sa survie future. La mise en oeuvre d'un projet d'acquisition de connaissances sur cette sous-espèce, et la surveillance de l'expansion de son aire de répartition seraient souhaitables.

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Status of the Weed Shiner, *Notropis texanus*, in Canada*

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Houston, J. 2001. Status of the Weed Shiner, *Notropis texanus*, in Canada. *Canadian Field-Naturalist* 115(4): 608–613.

The Weed Shiner (*Notropis texanus*) is known in Canada only from Manitoba, where it was first collected in 1982. It has, no doubt, occurred in the area for some time, but was misidentified as the Blackchin (*Notropis heterodon*) or Blacknose Shiner (*Notropis heterolepis*). It does not seem likely that its presence is a result of introductions, but by natural dispersal through the headwaters of the Mississippi to the Winnipeg-Rainy River headwaters. Canadian populations appear to be stable.

Le méné diamant (*Notropis texanus*) est connu au Canada seulement du Manitoba d'où il était premièrement recueilli en 1982. Sans doute il se produisait dans la région depuis quelque temps, mais mal identifié avec le menton noir (*Notropis heterodon*) et/ou le museau noir (*Notropis heterolepis*). Il n'est pas probable que sa présence est au cause de une introduction d'homme, mais par une dispersion naturelle au travers les eaux à l'amont de la rivière Mississippi de l'amont de la rivière Winnipeg-Rainy. Au Canada l'espèce semble stable.

Key Words: Cyprinidae, cyprinids, minnows, shiners, Weed shiner, méné diamant, *Notropis texanus*, rare fishes, endangered species, Manitoba.

The Weed Shiner, *Notropis texanus* (Girard, 1856), is a small cyprinid which has a nearly discontinuous North American distribution. There is a northern group in the upper Mississippi watershed in northern Illinois, Iowa, Wisconsin, Missouri and Minnesota, with rare records in Red River headwaters in northwest Minnesota. This group is not common. A lower Mississippi group starts at about the confluence of the Mississippi and Ohio Rivers and goes south from there, spreading along the Gulf Coast from the Florida Panhandle to coastal Texas (Swift in Lee et al. 1980 et seq.) Becker (1983) and Eddy and Underhill (1974) report that the range of Weed Shiners is decreasing in Wisconsin and Montana, respectively. Although it ranges north to Minnesota, and Illinois (Swift 1980) it is unknown in the Lake Superior drainage and until 1982 had not been recorded in Canadian waters. Stewart (1988) provides a record of the first Canadian collections in Manitoba.

Description

The Weed Shiner (Figure 1) is a small cyprinid rarely exceeding 6.5 cm in length. It is cylindrical in form and slightly compressed with an intense black lateral stripe which extends from the snout to the caudal peduncle where it ends in a black spot. Dark pigmentation may continue into the caudal fin rays. Dark pigment spots may be found on scales below the lateral line. Overall the Weed Shiner is straw coloured and is lighter on the sides and the belly. There is an obvious diffuse light stripe just above the

dark lateral band. The dorsal fin originates anterior to the posterior insertion of the pelvic fins and the anal has seven rays. The mouth reaches the anterior margin of the eye and the upper jaw does not protrude beyond the tip of the snout, the lower jaw being included in the upper. There are two rows of pharyngeal teeth (2, 4–4, 2 modal count), the presence of two on the inner row being diagnostic for *Notropis texanus* (K.W. Stewart, Department of Zoology, University of Manitoba, Winnipeg, Manitoba; personal communication). The lateral line has 34 to 37 scales (Eddy and Underhill 1974; Smith 1979; Becker 1983).

Weed Shiners are very similar to the Blackchin Shiner (*Notropis heterodon*) and the Blacknose Shiner (*Notropis heterolepis*) which have been collected in the Winnipeg River as far downstream as Great Falls (Stewart 1988). It also superficially resembles the Spottail Shiner (*Notropis hudsonius*) and the Bluntnose Minnow (*Pimephales notatus*). All four species can be distinguished from the Weed shiner and each other by use of morphometric and meristic features described above and elsewhere (e.g. Scott and Crossman 1973). However, the character values are variable and distinguishing the species from other local "blackline" shiners is extremely difficult. It also resembles the River Shiner (*Notropis blennioides*), but it lacks the lateral prominent black stripe and the River Shiner is not known from the Winnipeg River watershed (Stewart 1988).

Distribution

This is a lowland species which ranges from the Suwannee River of Florida and Georgia west to the Neches River in Texas, north along the Mississippi Valley to the Red River of the North in Minnesota and in drainage of lakes Michigan and Huron (Figure

*Reviewed and approved by COSEWIC April 1999, status assigned — Not At Risk.



FIGURE 1. Left side of a 29 mm specimen of the Weed Shiner, *Notropis texanus*, collected from the Winnipeg River on 20 September 1986 [reproduced from Stewart (1988) by permission].

2). It is not found in the upper Ohio River Basin or in the Lake Superior drainage (Swift 1980). The species has not been found in northwestern Ontario despite attempts to find it there (E. Holm, Royal Ontario Museum, Toronto, Ontario; personal communication).

In Canada the species is known only from Manitoba (Figure 3), where it was first collected in 1982 from the Ochre River (51°E17'N 99°E48'W), although the first recorded collection was upstream of the Great Falls Dam in the Winnipeg River (50°E28'N, 96°E00'W) in 1986 (Stewart 1988, Table 1). Specimens had previously been taken from Lake Dauphin (51°E12'N, 99°E34'W) between 1982 and 1986, but misidentified as Blackchin Shiners (Stewart, personal communication). Further collections have been made in the Icelandic River, south of Riverton, Manitoba, in Dauphin Lake, and the Winnipeg River above and below the Pine Falls Dam (Stewart, personal communication, Table 1) and north along the east side of Lake Winnipeg to Poplar River.

Protection

In the U.S. the species has declined in Wisconsin where it has been given Protected Status, and is considered of Special Concern in Iowa (Johnson (1987). A survey of state agencies in 1995 indicated that the Weed Shiner was endangered in Illinois, Iowa and Michigan and of special concern in Wisconsin.

In Canada, the fish are not subject to any protected status. General protection could be afforded if required under Manitoba provincial wildlife and endangered species legislation. The Provincial Conservations Status Rank is S4 (secure).

Population Sizes and Trends

The species is apparently common in the south, but

rare north of Arkansas (Swift 1980). It has declined in Illinois (although never abundant there), apparently due to siltation and general deterioration of water quality (Smith 1979). It also declined in Wisconsin (Becker 1983), Minnesota (Eddy and Underhill 1974), Illinois, Iowa and Michigan.

There is no evidence on which to base information on populations sizes and trends from Manitoba. The 1986 collections (Table 1) yielded 53 under-yearlings, and in 1987, 292 specimens ranging in length from 18.5 to 39.1 mm Standard Length (S.L.) were taken from two locations (50°E28'N, 96°E00'W and 50°E26'N, 96°E00'W) on the south shore of the forebay of the dam during the same collections (212 in 1986 and 80 in 1987). Both sexes were present in these collections and fish over 30 mm S.L. showed evidence of sexual maturity (Stewart 1988). No information on specimens taken in other collections is available.

The Weed Shiner is apparently widely distributed in tributaries of the east side of Lake Winnipeg, extending northward to almost the north end of the lake. In addition, it has been found in the Icelandic River, a tributary of the west side of the south basin of Lake Winnipeg, and west to Lake Dauphin. In suitable habitat, it seems to be abundant. Manitoba, may in fact, be a refuge for the northern stocks of this species, given that its distribution in the North-Central United States seems to be shrinking mainly due to habitat loss. By contrast, its distribution in Manitoba suggests that it has been there for a long time and the known populations seem to be stable. The more remote of those populations also seem to be protected, at least for the present, from human impact. The spread of commercial wild rice culture could become a threat to Weed Shiner habitat in the future, but has not affected any of the known locations thus far.

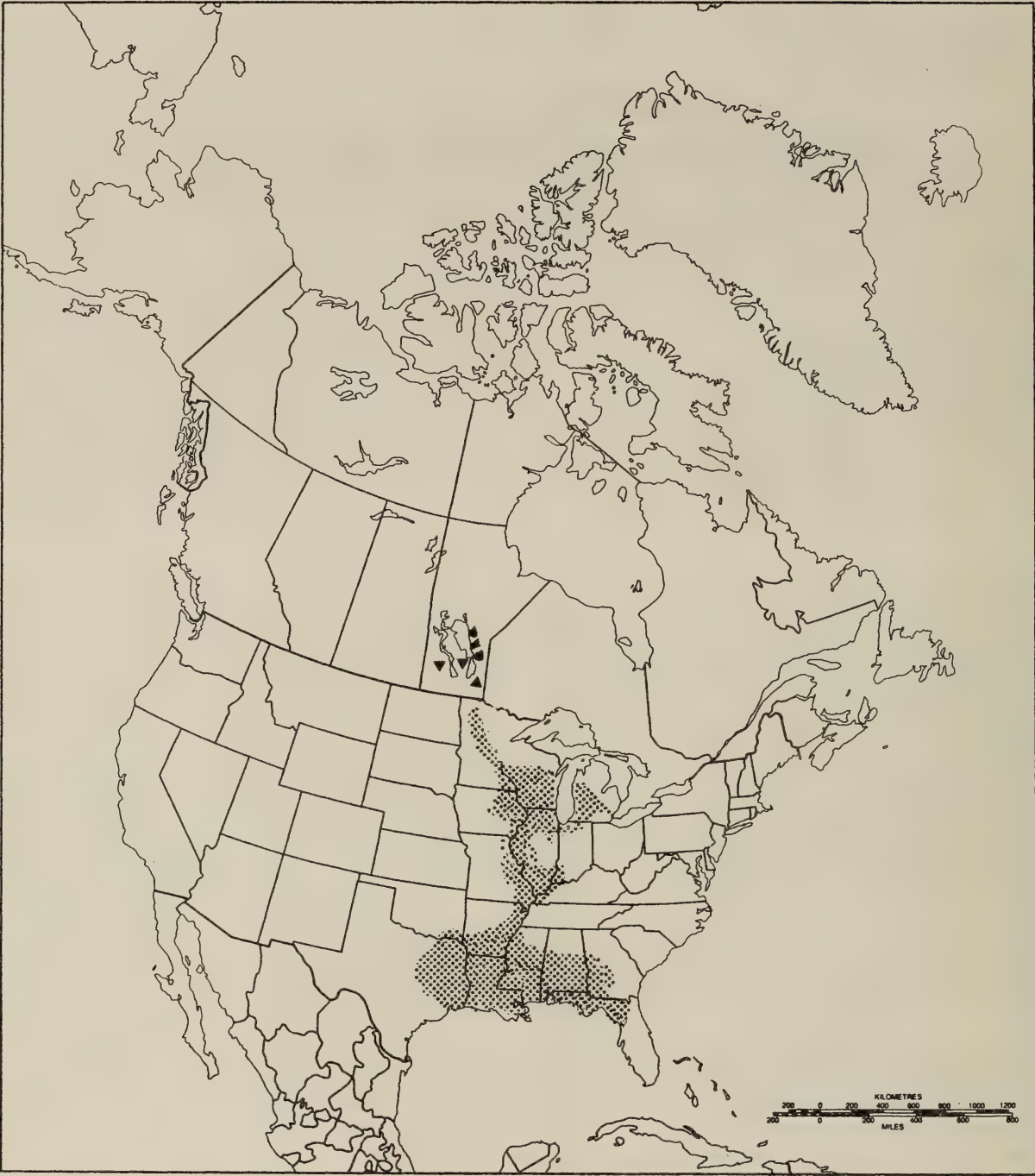


FIGURE 2. North American distribution of the Weed Shiner, *Notropis texanus* (Swift 1980; Stewart 1988).

The site of the nearest Manitoba collections is 435 km linear distance north-northeast of the Otter Tail River (tributary to the Red River of the North) in Minnesota, the previously known extent of the northern occurrence of the species (Stewart 1988). It is not currently known from elsewhere in the Hudson Bay drainage (Stewart 1988), although Hubbs and Greene (1928) reported Weed shiners from the St Croix River, but Eddy and Underhill (1974) have found no evidence of the species there. Its presence in Manitoba is most likely the result of a post-glacial invasion from the south (Crossman 1991) as apposed

to transport by man since it is not commonly used as a bait fish as it does not survive well in a bucket and is smaller than minnows usually used as bait (Stewart 1988), although it may be more commonly used for bait in southern states. Given its known distribution in Manitoba, the species has undoubtedly been there for some time and has gone unnoticed or been misidentified as the Blackchin or Blacknose Shiner. The distribution of the species suggests rather recent post-glacial dispersion from the Mississippi River headwaters in Minnesota into the headwaters of the Winnipeg-



FIGURE 3. Manitoba sites of Canadian collections of the Weed Shiner, *Notropis texanus* (Stewart 1988).

Rainy River system and subsequent downstream dispersal (see Crossman and McAllister 1985; Stewart 1988). Although it is not now present in the Minnesota headwaters of the Mississippi it apparently once was (Hubbs and Greene 1928) and should be looked for there and in the Rainy River, although attempts to find it there have so far proved fruitless (Holm, personal communication).

Habitat

The Weed Shiner is commonly found in sand bottomed streams of varying sizes and low gradient and in the slower moving regions of higher gradient streams in the south (Heins 1977; Smith 1979). In the north they are most often found in clear, protected weedy streams, lakes and larger rivers (Eddy and Underhill 1974).

In Manitoba the species was found in the Winnipeg River in waters of pH 8.5, 0.8 to 1.2 m deep over silty or muddy substrate with thick beds of submerged aquatic vegetation (Stewart 1988). The water was stained slightly brown and varied from clear to

turbid depending on wind direction. Water temperatures were 21°C in August and 16.5°C in September.

Ross and Baker (1983) found that Weed Shiners were a flood exploitive species, being more abundant in years following non-destructive floods on low gradient streams than in low flood years. This suggests that the species may utilize floodplains for breeding. Kwak (1988) also found the Weed Shiner to be a flood exploitive species using the floodplain as a nursery area and returning to backwater areas when forced off the floodplain by receding water levels.

Biology

Little information is available on the biology of the species. It apparently breeds during March to April in the extreme south, during May in Missouri and June in Minnesota (Swift 1980). Heins (1977) discussed age and growth in Mississippi and found that the life span is two to three years, 60% of the growth is attained in the first year of life.

Limiting Factors

The species appears to have a narrow range of habitat requirements and responds quickly to changes in habitat and water quality. Smith (1979) indicated that Weed Shiners declined in Illinois waters at locations where human or other disturbances resulted in increases in turbidity and siltation or decreased aquatic vegetation. Similar results have been noted in Wisconsin (Becker 1983) and Minnesota (Eddy and Underhill 1974).

Special Significance of the Species

The Weed Shiner is probably an important forage species where abundant, it is not suitable as a bait fish as it does not survive well in a bucket and is smaller than preferred minnow size (Stewart 1988).

The recent discovery of the Weed Shiner in Canada, its disjunct distribution, and habitat requirements are of interest to science in relation to the zoogeographic history and distribution of species subsequent to the Wisconsinan Period of glaciation. Its critical habitat requirements could also make the species a useful indicator of changing water quality, if the previous occurrence at a specific site were known.

Evaluation

The Weed Shiner is probably threatened in every northern state in which it occurs because of loss of the clear, weedy habitat it requires as the species is intolerant of turbidity, pollution or habitat degradation (Stewart, personal communication). The species has obviously been in Manitoba for some time, and has been misidentified as the Blackchin and/or Blacknose Shiner until recently. It may be that the

TABLE 1. Manitoba collection records for *Notropis texanus*, the Weed Shiner [from University of Manitoba, Royal Ontario Museum (ROM) and National Museum of Natural Sciences (NMNS) collections.

Date	Location	Coordinates	Number of Specimens
~/07/82	25 km (by air) northwest of Ochre River (NMNS 83 0186)	51°E17'N 99°E48'W	
14/06/84	Ochre River, 0.2 km from mouth	51°E06'N, 99°E45'W	3
12/07/84	Ochre River mouth	51°E06'N 99°E45'W	5
20/09/86	Winnipeg River just above Great Falls Dam	50°E28'N, 96°E04'W	47
11/08/87	Winnipeg River 3.6 km above of Great Falls Dam (ROM52608)	50°E28'N, 96°E00'W	212
20/09/87	Winnipeg River just above Great Falls Dam (ROM51886)	50°E27'N, 96°E01'W	
23/09/89	Icelandic River at Highway 8	51°E02'N, 97°E43'W	39
12/08/91	Poplar River, sandy bay 2 km above Lake Winnipeg	53°E00'N, 97°E24'W	1
13/08/91	Poplar River, below lowermost falls	53°E00'N, 97°E22'W	2
15/08/91	Mouth of Berens River	52°E21'N, 97°E03'W	6
15/08/91	Berens River, just east of I.R.	52°E21'N, 96°E58'W	98
15/08/91	Etomani River, just below lowermost rapids	52°E19'N, 96°E54'W	34
21/09/91	Winnipeg River 3.6 km upstream of Great Falls Dam	50°E28'N, 96°E00'W	3
21/09/91	Winnipeg River at Abbitibi boat dock, Pine Falls	50°E34'N, 96°E12'W	2
03/06/92	Fisher River at rock bridge on I.R.	51°E26'N, 97°E17'W	4
03/06/92	Icelandic River just below dam upstream of Highway 8	51°E02'N, 96°E58'W	47
12/08/92	Bloodvein River, 0.5 km above Lake Winnipeg	51°E47'N, 96°E43'W	1
13/08/92	Bloodvein River, 1 km downstream of Wolf Rapids	51°E43'N, 96°E43'W	9
13/08/92	Bloodvein River just upstream of I.R.	51°E45'N, 96°E43'W	92
18/08/92	Pigeon River at mouth	52°E16'N, 97°E02'W	21
19/08/92	Pigeon River, in abandoned channel	52°E16'N, 96°E59'W	9
29/06/93	Icelandic River between Riverton and Highway 8	51°E00'N, 96°E51'W	4
28/07/93	Icelandic River at Highway 8	51°E00'N, 97°E00'W	10
18/09/93	Winnipeg River 3.6 km upstream of Great Falls Dam	50°E28'N, 96°E00'W	126
24/09/94	Winnipeg River 3.6 km upstream of Great Falls Dam	50°E28'N, 96°E00'W	70
~/09/95	Winnipeg River at St Georges, just above Pine Falls Dam	50°E31'N, 96°E12'W	
~/09/96	Winnipeg River at St Georges, just above Pine Falls Dam	50°E31'N, 96°E12'W	
19/09/97	Winnipeg River 3.6 km upstream of Great Falls Dam	50°E28'N, 96°E00'W	80
~/09/97	Winnipeg River at St Georges, just above Pine Falls Dam	50°E31'N, 96°E12'W	

species has a refuge here, but industrial, urban and agricultural activity may result in habitat degradation as in the northern U.S.

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Status of The Bridle Shiner, *Notropis bifrenatus*, in Canada*†

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The Bridle Shiner is a small minnow that is restricted to the Atlantic drainage of eastern North America. In Canada, it is found in lowland areas of eastern Ontario and southwestern Québec where it is generally rare. It is usually found associated with aquatic vegetation where it breeds and finds food and protection from predators. Although it appears to be stable in a few areas, the Bridle Shiner has apparently declined in most of the river systems that have been recently resurveyed. The status of this species in many other waters where it has been captured is unknown because there have been no surveys there since the 1970s. Its decline is probably as a result of poor water quality, high turbidity, and decrease in suitable aquatic vegetation particularly in small rivers of the agricultural zone. It is recommended that the Bridle Shiner be classified as Vulnerable in Canada.

Le méné d'herbe est un petit cyprinidé dont la répartition est restreinte au bassin de drainage Atlantique de l'Amérique du Nord. Au Canada, sa présence a été rapportée dans les basses terres de l'est de l'Ontario et du sud-ouest du Québec; il est généralement rare. Ce cyprin est associé à la végétation aquatique, au sein de laquelle il se reproduit, s'alimente et s'abrite. La présence de cette espèce n'a été reconfirmée que dans une minorité de cours d'eau ou sections de cours d'eau ayant été l'objet d'inventaires répétés au cours des 50 dernières années. Son déclin est probablement relié à la dégradation de la qualité de l'eau, à l'accroissement de la turbidité et à une diminution de la disponibilité des herbiers aquatiques propices à l'espèce, et ce particulièrement dans les petits cours d'eau en zone agricole. Au Canada, le méné d'herbe devrait être considéré comme une espèce vulnérable.

Key Words: *Notropis bifrenatus*, Bridle Shiner, méné d'herbe, Ontario, Québec, status, vulnerable.

The Bridle Shiner, *Notropis bifrenatus* (Cope) (Figure 1), is a small member of the minnow family (Cyprinidae) that reaches a maximum size of 50 mm standard length. It is one of five species of *Notropis* in Canada with a prominent black lateral band which extends from the tail and continues on to the snout. There is often a bold caudal spot which is confluent with the midlateral stripe. The black band is particularly obvious in most preserved specimens but may be obscured in living specimens by the silvery scales. The Bridle Shiner gets both its common and scientific names from the appearance of the black pigment on the snout and upper lip. The black band narrows toward the tip of the snout and, at its end, is restricted to the upper lip. The lower lip has little or no pigment. The eye is one of the largest in Canadian cyprinids, its diameter ranging from 31.2 to 38.8% of head length (Scott and Crossman 1973). The mouth usually extends to below the posterior half of the nostril. It is terminal to subterminal with the tip of the upper jaw projecting ahead of the tip of

the lower jaw and the snout rarely protruding beyond the tip of the upper jaw. Principal anal rays are usually seven, although Scott and Crossman (1973) recorded 32% of specimens with eight. Male *Notropis bifrenatus* develop minute nuptial tubercles on the head, nape and pectoral fin (Jenkins and Burkhead 1993).

Life colours of *N. bifrenatus*, have been described by Scott and Crossman (1973) and Jenkins and Burkhead (1994). In life, the back is straw coloured and there is a green blue iridescence on the sides giving rise to the name "bluesides" used by one bait fisherman in the Lake St. Francis area. During the breeding season there is sexual dimorphism, males are bright yellow or golden on the lower sides, and the first 5 or 6 pectoral rays are margined with brown. The back is darker than in spawning females and non-breeding males. When breeding, both sexes develop yellow fins (Harrington 1947).

Taxonomy

Class: Actinopterygii

Order: Cypriniformes

Family: Cyprinidae

Scientific Name: *Notropis bifrenatus* (Cope, 1869)

English Common Name: Bridle Shiner

French Common Name: méné d'herbe

Comments: Gilbert (1980) suggested that the closest rela-

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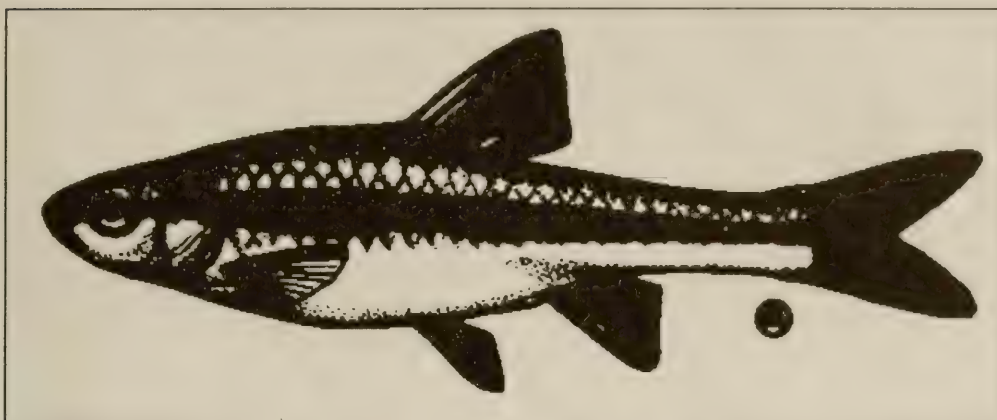


FIGURE 1. Bridle Shiner, *Notropis bifrenatus*, female, 53 mm TL, ROM 21671. Fall Creek, Thompsons County, New York State. Drawn by Anker Odum, from Scott and Crossman (1973), by permission.

tive of *Notropis bifrenatus* is the Blackchin Shiner, *Notropis heterodon*. Although one study (Mayden 1989) referred *N. bifrenatus* to *Hybopsis*, this classification is subject to change and we follow Robins et al. (1991) until the interrelationships between the species of *Notropis* and *Hybopsis* are better known. Coburn and Cavender (1992) retain *Notropis* for *N. bifrenatus*.

Distribution

The Bridle Shiner is restricted to eastern North America in the Atlantic drainage from western Lake Ontario east to Maine and south to South Carolina (Gilbert 1980; Jenkins and Burkhead 1994). (See inset, Figure 2)

In Canada, it is restricted to the eastern part of what is known as the Mixedwood Plains ecozone (Wiken 1986; Crossman and Holm 1997). It is found from the Bay of Quinte, Lake Ontario, east and north to Lac St-Paul, near Trois-Rivières, Québec and south to Lac Memphrémagog (Figure 2) but not south in Vermont (see inset, Figure 2). It is found in lowland areas and does not occur far inland from the St. Lawrence River or Rivière Richelieu.

Because the species is difficult to identify, some specimens in the collections of the ROM and the Canadian Museum of Nature (CMN) were re-examined. Two lots in the ROM collection were questionable but their identity as *Notropis bifrenatus* could not be ruled out completely and they have been included as valid records: (1) The only record from the Napanee River has poor locality data but may be west of the Bay of Quinte. The single specimen (ROM 24732) captured by the Department of Planning and Development in 1950, lacks a prominent lateral band and has 8 anal rays which is uncommon for *Notropis bifrenatus*. *Notropis volucellus* and *Notropis stramineus* are shiners that are similar to *Notropis bifrenatus* but lack a prominent lateral band. However, it is not *Notropis volucellus* because it has anterior lateral line scales which are not elevated, and it is probably not *Notropis stramineus* because it has

eight anal rays. (2) One hundred and forty-nine of the 154 specimens identified as *Notropis bifrenatus* captured in Browns Bay in 1959 (ROM 23628) were re-identified (by EH) as *Notropis stramineus* (140), *Pimephales notatus* (8), and *Cyprinella spiloptera* (1). The remaining five specimens were cleared and stained and it was not possible for us to confirm their identification. However, those cleared and stained specimens could be *Notropis bifrenatus* as they were larger than the rest and therefore would have been easier to identify originally. Four of the five specimens had seven anal rays and the fifth had eight, likely counts for *Notropis bifrenatus* but also for *Notropis stramineus*. A small specimen at the Canadian Museum of Nature (CMN) identified as *Notropis bifrenatus* (NMC 74-0106) from Lac à la Pêche in Parc National de la Mauricie, Québec, was reidentified as *Semotilus corporalis* (by EH).

The range of the Bridle Shiner in Canada has changed little from what was known in the 1940s. The species was first documented in Québec by Cuerrier et al. (1946) from the Montréal and Lac St-Pierre regions. In Ontario, it was first captured in 1928 in the Bay of Quinte at the east end of Lake Ontario (Hubbs and Brown 1929). By 1938, collections by G. C. Toner (ROM collection) had extended the range northeastward into an unnamed tributary of the Rideau Canal near Brewer's Mill, and eastward into the Gananoque River, the St. Lawrence River near Gananoque, and in a tributary of Lake St. Francis. Radforth (1944) favoured the idea that *Notropis bifrenatus* had dispersed into Ontario from the Atlantic refugium either through the Mohawk-Hudson outlet or through the Champlain outlet. Its common occurrence in the upper Richelieu suggests that it used the latter means of post-glacial dispersal. Radforth (1944) suggested that it had arrived in Ontario only recently and had possibly not reached its limit owing to insufficient time for dispersal. However, Scott and Crossman (1973) predicted that the expansion of the range of the Bridle Shiner in

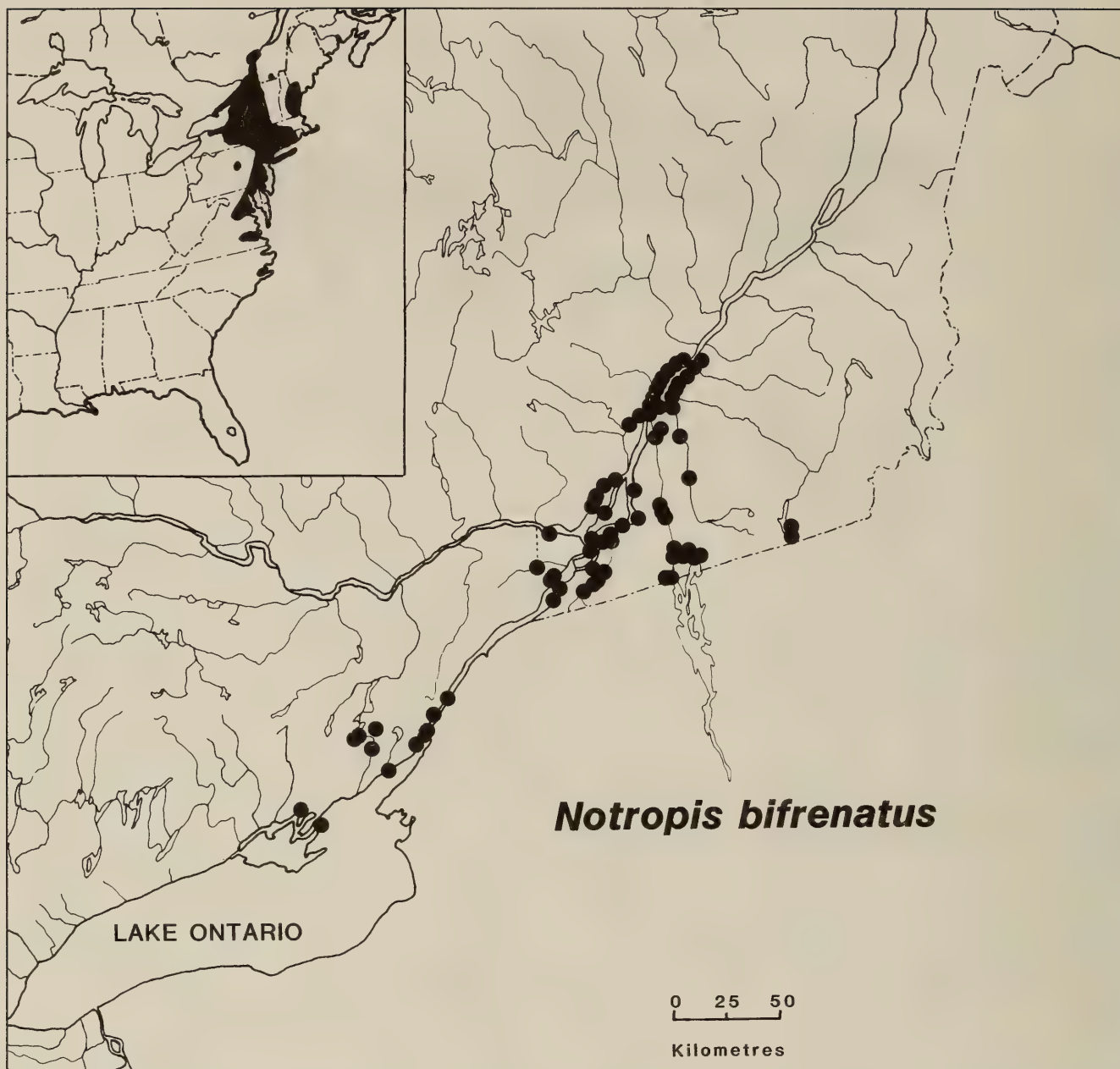


FIGURE 2. Distribution of the Bridle Shiner, *Notropis bifrenatus*, in Canada. A point may represent more than one capture at different sites within the area of the circle. Inset: North American distribution modified from Gilbert (1980).

Canada would be prevented owing to sewage disposal problems caused by high population pressures and industrialization. Further range expansion is likely prevented by other factors such as water temperature, intolerance to acidity and lack of suitable habitat (clear, vegetated creeks and rivers).

Protection

The Bridle Shiner is a species of concern in North Carolina (Johnson 1987). Jenkins and Burkhead (1994) recommended that the species be granted special concern status in Virginia and suggested that the status should be ascertained in other states. Global and North American federal, state and provincial conservation status and ranks were obtained from the

Eastern Regional Office of the Nature Conservancy, Boston, dated 9 June 1997. The ranks assigned to the Bridle Shiner indicate that for those states where abundance is classified, abundance ranges from being very common to very rare throughout its range:

Global Rank: G5

National Ranks: United States: N5; Canada: N4

Regional Ranks: Connecticut: S3; Washington, DC: unknown; Delaware: unknown; Massachusetts: unknown; Maryland: S3; Maine: S2; North Carolina: Historical¹; New

¹Historical = not captured in the recent past, but not considered extirpated.

Hampshire: S4; New Jersey: S4; New York: S5; Ontario: S3; Pennsylvania: S2; Québec: S4; Rhode Island: S5; Virginia: S3; Vermont: S3S4; 1 = extremely rare, 2 = very rare, 3 = rare to uncommon, 4 = common, 5 = very common

In Canada, there is no specific protection, but the Bridle Shiner receives nominal protection from the federal Fisheries Act, particularly section 35(1) which states that a development proposal must not cause a "Harmful Alteration, Disruption, or Destruction" of fish habitat (Minns et al. 1995). Habitat may also be protected by other federal legislation including the Environmental Assessment Act, Environmental Protection Act and Water Act.

In Québec, habitat is generally protected by "Loi sur la qualité de l'environnement" (Environmental Quality Act). Fish habitat is also protected by the "Loi sur la conservation et la mise en valeur de la faune" (Act respecting the conservation and development of wildlife) which, under articles 128.1 to 128.18, controls activities that could modify biological, physical or chemical components peculiar to fish habitat. The "Loi sur les espèces menacées ou vulnérables" (Act respecting threatened or vulnerable species) makes additional provision for the protection of the habitat of threatened or vulnerable species.

Ontario legislation which may protect habitat includes the Environmental Protection Act, Environmental Assessment Act, Game and Fish Act, Planning Act, and Water Resources Act. Aquatic habitats in Ontario tributaries of Lake St. Francis below Highway 2 which contain populations of Bridle Shiners (e.g., Gunn and Wood creeks) are protected against wetland fill-in by an Act administered by the Raisin River Conservation Authority (Anne Bendig, Ontario Ministry of Natural Resources (OMNR), personal communication). See also Habitat.

Population Size and Trend

Population sizes for the Bridle Shiner have not been estimated in Canada. However, changes in population size may be inferred from sampling data (summarized details of records of occurrence of the Bridle Shiner in Ontario and Quebec are on deposit with the COSEWIC Secretariat). Although the number of specimens is sometimes given, this number is dependent on effort and method of capture and is only a rough indicator of relative abundance compared to other species. Population trends are obscured by the difficulty of identification of the species and many of the specimens are no longer available for identification confirmation. Records of occurrence of the species (number of records in brackets) were obtained from Ministère de l'Environnement et de la Faune du Québec (MEF), formerly Ministère du Loisir, de la Chasse et de la Pêche (MLCP) and Ministère de l'Environnement du Québec (MENVIQ) (425), Royal Ontario Museum (ROM) (22), OMNR (12), University of Michigan

Museum of Zoology (UMMZ) (7) and Canadian Museum of Nature (NMC) (3).

Jenkins and Burkhead (1994) documented several areas in the United States where the Bridle Shiner has declined or been extirpated. They consider that the Neuse River population in North Carolina is probably extirpated. In Virginia, some populations are extirpated or nearly so and the range of the species has receded sharply in Massachusetts, New Jersey, Pennsylvania and Maryland. Cooper (1983) indicated that the Bridle Shiner was once abundant in eastern Pennsylvania but is now taken only rarely, and only in the Delaware River drainage. Page and Burr (1991) indicated that it was fairly common but decreasing in some areas of its range (see also Nature Conservancy ranks under Protection).

In Canada, evidence suggests that populations have declined in several river systems such as the St-François, aux Brochets, Richelieu, Châteauguay, St-Laurent (Lac St-Louis and Lac St-François). There is no evidence of decline in recently surveyed waters in the St. Lawrence River around the Thousand Islands, two Ontario tributaries of Lake St. Francis, Lac St-Pierre and Lac St-Pierre Archipelago. Lack of adequate recent sampling makes it difficult to determine its status in other waters of its Canadian range such as lakes in the Rideau canal system, other tributaries of Lake St. Francis (on the Ontario side), Lac Memphrémagog, and Lac St-Paul.

In Lac St-François, the species was reported at the mouth of Rivière à la Guerre in 1941 and 1945 and in the northeastern part of the lake in 1968 (Mongeau 1979a). No Bridle Shiners were captured during the fall of 1996 in 40 seine stations evenly distributed along the Québec shore of the lake (Fournier et al. 1997). The identification of the 1941 specimens were confirmed by two of us (JL and PD).

It would appear that *Notropis bifrenatus* was most abundant in the channels of Îles de Sorel and Îles de Berthier (Lac St-Pierre Archipelago) where 5387 specimens were captured in 143 of 294 stations sampled between 1970 and 1971 (Massé and Mongeau 1974). In that region it was more common than the related Blackchin Shiner and Blacknose Shiner, *Notropis heterolepis*. The Bridle Shiner was also abundant in Lac St-Pierre where 727 specimens were captured in 65 of 134 stations. Twenty-seven sites on 12 tributaries of the south shore of Lac St-Pierre were sampled in 1982. The species was not recorded in those tributaries, although the Blacknose Shiner which is easily confused with the Bridle Shiner, was recorded from two of the sites (McFarlane and DuRocher 1984). Lac St-Pierre has also been sampled by MEF during fall 1995: 330 specimens were captured in 15 of the 36 seine stations distributed on the littoral zone of the lake; 84% of these specimens were captured at three stations. In the Lac St-Pierre Archipelago, 61 specimens were captured in 8 of the

40 stations evenly distributed along the numerous channels. This recent sampling indicates that the Bridle Shiner is still well-established in Lac St-Pierre and Lac St-Pierre Archipelago (Fournier et al. 1996).

In the Rivière Yamaska basin this species occurred only in the lower part where it was found in 12 of 210 seine hauls made between 1963 and 1971 (Mongeau 1979b). A total of 16 specimens of the species were captured on 22 August 1989 in that river near its mouth (ROM 57019). However, it was not captured at any of four sites within the known range of the species in a 1995 electrofishing survey of 39 sites in the Rivière Yamaska (La Violette 1997).

It appears to have been reduced in the Rivière Châteauguay system. It was found mainly in the lower part of the basin in 1968. Between 1975 and 1976 it occurred in 21 of 217 seine hauls in that system. However, in 1993 it was not recorded at any of the 21 sites electrofished by the Ministère de l'Environnement et de la Faune (La Violette and Richard 1996).

The species was caught during the 1940s in Rivière Saint-François, but was not reported in this river by Mongeau and his colleagues in the 1960s and 1970s (Mongeau and Legendre 1976) or in any of the 26 sites sampled on the Rivière Saint-François during 1991 (Richard 1996). Its presence has also been reported in 1941, in Rivière aux Brochets, near the outlet, but not in the 1970s, during the systematic survey of this river by Mongeau (1979c). However, during spring 1990, six Bridle Shiners were captured in la Baie Missisquoi of Lac Champlain near the mouth of this river.

The species was frequently encountered between 1965–1970 in the Rivière Richelieu where it was found at 98 of 623 stations (Mongeau 1979c). In the lower Richelieu, between Chambly and Saint-Marc, 27 specimens were collected in August 1970 (in 49 seine hauls). In 1989, six specimens were captured by the ROM in the upper basin near the United States border (ROM Accession 5518). In 1993, none were caught in 129 seine hauls, during a survey in August and September (Jean Leclerc, unpublished data). In 1995, one specimen was caught in one of 21 electrofishing stations 100 km from the mouth of the Richelieu (Saint-Jacques and Richard 1997). Therefore, the Bridle Shiner is still present in the Richelieu but recent surveys suggest that its abundance has decreased since 1970.

Notropis bifrenatus was reported in the 1940s, 1960s and 1970s in Lac Saint-Louis but was absent from the 1982–1983 seine catch of Beaulieu (1988) in the littoral and vegetated zone of that lake ($n = 61$ seine hauls). During fall 1997, La Société de la faune et des Parcs du Québec (FAPAQ) seined 46 seine stations evenly distributed along the shoreline and

islands of Lac St-Louis. Of a total of 16 424 fishes, only one Bridle Shiner was reported from a site in Les Îles de la Paix Archipelago, along the southern shore. During fall 2001, FAPAQ seined 115 stations evenly distributed in the section of the St. Lawrence River between Montreal and Contrecoeur, 25 km downstream of Montreal. Of a total of 23 514 fishes, 103 Bridle Shiners were captured at three of the stations.

In Ontario, there are few records and the species has always been rarely encountered. It appears to be stable in some areas but insufficient recent sampling makes it impossible to ascertain its status in other areas. In 1994, a survey by ROM sampled 13 sites in the Ontario range of the species. The Bridle Shiner had been previously recorded from seven of those sites. It was captured at three of the 13 sites and constituted 3.9–23.7% (= 6.6%) of the catch at those three sites. Attempts to capture the species in Sutherland and Finney creeks, and an unnamed creek near Brewers Mills failed but the Bridle Shiner was caught in Wood Creek, the St. Lawrence River in the Thousand Islands region, and in Jones Creek, a new location.

Recent fieldwork by ROM, OMNR, and the New York Department of Environmental Conservation (see Carlson 1995) have documented several captures of *Notropis bifrenatus* from the St. Lawrence and some of its tributaries. In 1991–1994, Bridle Shiners were recorded at 12 of 59 sites seined in a juvenile musky study. They constituted 0.03–70.1% ($\bar{x} = 7.2\%$) of the catch at each site (Anne Bendig, OMNR, St. Lawrence River Fisheries Unit, unpublished data). Some of these capture records may have represented Blackchin, Blacknose and/or Pugnose Shiners (*Notropis anogenus*). In 1994, the senior author sampled three of the OMNR sites where Bridle Shiners had been recorded and found them at two of the three sites. It is therefore likely that a majority of Bridle Shiner records documented by the OMNR are correct and we have considered all of them valid.

According to surveys in New York in the Thousand Islands region of the St. Lawrence River, the species has fluctuated in abundance over the last 60 years. It was common in the 1930s when it was found in 64% of collections. But in 1976 it was found in only 2% of collections. It was more common in 1993–1994 when it occurred in 26% of collections (Carlson 1995). The reason for its resurgence may relate to the increase in the clarity of the water (see Habitat) although differences in sampling personnel, gear and sites sampled could also be factors.

Habitat

Notropis bifrenatus is a warmwater fish that is found in quiet areas of streams and occasionally in standing water. It is found over a soft bottom of sand, silt, and detritus. It prefers colourless or moderately stained water and avoids turbid areas (Scott

and Crossman 1973; Smith 1985; Jenkins and Burkhead 1994). It is tolerant to brackish water but is not acid tolerant which will likely prevent its spread in acid sensitive areas on the Canadian Shield. Carlson (1995) noted that in the Thousand Islands region of the St. Lawrence River, *Notropis bifrenatus* and *Notropis heterolepis* are more common than *Notropis heterodon* and *Notropis anogenus*, other "blackline" shiner species with similar habitat requirements occurring there.

In Ontario, the Bridle Shiner is primarily restricted to quiet areas of creeks and the St. Lawrence River, but has also been found in small lakes. It is usually associated with submerged, floating or emergent aquatic macrophytes. The substrate does not seem to be critical as it occurs over a variety of bottom types including organic detritus, clay, silt, gravel, rubble and rocks. Although it is reported to be intolerant to turbidity it was captured at two sites where the water was described as turbid and at two other sites with secchi disk readings of 0.5 and 0.7 metres (ROM collection records).

In Québec, this minnow was found in relatively high frequency in sectors characterized by slow current, dense aquatic vegetation and highly developed shoreline perimeter along the numerous islands of Fleuve Saint-Laurent, the upper part of Rivière Richelieu and Rivière des Milles Iles and Lac Saint-Pierre. In the Lac St-Pierre Archipelago, during fall 1995, 3 or the 8 stations where the Bridle Shiner was captured had low transparency (0.5–0.7 m). Fifteen of 61 Bridle Shiners collected in the Archipelago were captured in these stations.

Harrington (1947) reported that the Bridle Shiner spawned among submerged aquatic plants (primarily *Myriophyllum* and *Chara* adjacent to other types of submerged and floating vegetation) where there is 15–46 centimetres of free water above the vegetation. Some spawning occurred in relatively barren areas later in the spawning season.

Aquatic macrophytes are probably essential for nursery areas. Harrington (1947) found that the young of the Bridle Shiner were restricted to areas where spawning had occurred and were found among strands of *Myriophyllum*. Larvae have cement glands that allow adhesion to plants (Jenkins and Burkhead 1994).

In the Ontario portion of the St. Lawrence River, there has been an increase in water clarity which occurred about the same time that the exotic Zebra Mussel (*Dreissena polymorpha*) was first discovered there in 1989. It would be expected that aquatic vegetation would increase with increased clarity of the water, as it has in many other areas invaded by zebra mussels, but reports on abundance of aquatic vegetation have been conflicting. Anglers have reported reduced levels of macrophytes in May and June 1994. On the other hand, field work conducted by

the OMNR in August found aquatic vegetation unchanged from previous years. Reduced levels of aquatic vegetation may have resulted from severe ice scouring and reduced phosphorus levels. Phosphorus levels have declined over the last 30 years as the result of improved sewage treatment, decreased levels of industrial pollution, and less agricultural runoff. Reduction of aquatic vegetation will be offset by habitat restoration or habitat compensation programs which are designed to comply with the Fisheries Act's requirement for causing "no net loss or net gain" of fisheries habitat. (Anne Bendig, personal communication).

Some populations of Bridle Shiners may receive protection because they occur in the upper St. Lawrence River in the Thousand Islands National Park. However, they would suffer from the effects of turbidity and water pollution created by any construction projects and toxic effluent upstream of the Park.

General Biology

Reproductive Capability

The breeding of the Bridle Shiner in New Hampshire and New York was described in detail in several papers by Harrington (1947, 1948a, 1950, 1951). No individuals older than two years of age were found. Males normally spawned only once and most frequently in their first year. Females spawned in their first year if they reached 30 mm SL, but the majority spawned in their second year. The number of eggs ranged from 1062 for a 34 mm SL female to 2110 for a 44 mm SL female but many of these eggs, with diameters ranging from 0.2 to 0.8 mm, may not have matured in time to be spawned. This size difference in the eggs was thought to indicate an extended spawning season. In New Hampshire, the breeding season ranged from the last week of May to mid-July. In New York breeding activity began on 2 May and lasted until August but the height of activity occurred in mid-June. Spawning usually took place at 17–22°C but occurred at temperatures as low as 14°C and as high as 27°C. Eggs were broadcast on vegetation and no parental care was provided. Most or all eggs were eaten by parents before they reached the bottom in aquaria (Harrington 1951) but it is not known if a significant number of eggs are eaten in nature. The eggs are adhesive but it is not known if they attach to plants (Jenkins and Burkhead 1994).

Movement

No information on movement or migrations of the Bridle Shiner is available. It is not likely that this frail, slow-swimming fish has a large home range.

Behaviour and Adaptability

The Bridle Shiner is a sight feeder and feeds during daylight hours on microcrustaceans, aquatic insects, detritus and living plant material. Much of

this food is found either on or above submerged aquatic plants. It feeds on the bottom when and where the vegetation is sparse and lacking (see Harrington 1948b).

It is presumed that the Bridle Shiner is subject to heavy depredations by predators such as Northern Pike (*Esox lucius*), Grass and Redfin Pickerels (*Esox americanus*), Muskellunge (*Esox masquinongy*), Smallmouth Bass (*Micropterus dolomieu*), Yellow Perch (*Perca flavescens*), White Perch (*Morone americana*) and Black Crappie (*Pomoxis nigromaculatus*) (Scott and Crossman 1973) because of its small size and weak swimming ability (Harrington 1948a).

Limiting Factors

Increased turbidity adversely affects the ability of this species to locate its food and hinders the growth of submerged aquatic plants essential for feeding, reproduction and cover (Jenkins and Burkhead 1994). Wetland fill-in and physical removal of aquatic vegetation would also be expected to reduce populations. The composition of the aquatic macrophyte community is probably also important for suitable spawning areas and food. It may prefer to spawn over watermilfoil (*Myriophyllum*) and *Chara*. The presence of a clear area above the submerged vegetation (cf macrophytes that extend to the surface) is probably important for spawning activities (Harrington 1947). Thus any plant which has a tendency to grow to the surface before spawning occurs will have a deleterious effect on spawning success. The decline of the closely related Blackchin and Blacknose shiners have been associated with an explosion of the exotic Eurasian Watermilfoil, *Myriophyllum spicatum* in several Wisconsin lakes (Lyons 1989). Watermilfoil has been recorded in surveys by the OMNR (Anne Bendig, personal communication) but it is unknown whether this is a native *Myriophyllum* species or the introduced *M. spicatum*.

Since the 1960s and 1970s, characteristics of most of the rivers of the Saint-Laurent lowlands in Québec have been modified by urbanization and by an extensive agricultural development of corn cropping and hog-rearing. Pesticides and nutrient loading increased in many small rivers of these lowlands. With the exception of Fleuve Saint-Laurent, most of the sectors where *Notropis bifrenatus* has been reported now suffer from severe sedimentation and eutrophication. In Ontario, the streams affected by agricultural development are in the watershed of Lake St. Francis where feed-lot and dairy cattle are raised and mixed pasture and corn crops are grown. These streams (Wood, Gunn, Finney creeks) have been channelized for drainage of fields and have high loadings of pesticides, nutrients, and sediment (M. Eckersley, OMNR, Kemptonville, personal communication).

Special Significance of the Species

Wherever it occurs in sufficient numbers, the Bridle Shiner is presumably an important forage fish for a variety of important game fish (see *Behaviour and Adaptability*). Predators probably find the Bridle Shiner an easy target and a decline in numbers would have a negative impact on these sport and commercial fishes.

Because of its small size and rarity it has limited use as a bait species in Ontario. In Québec, this fish is not used as live bait for sport fishing.

The Bridle Shiner, is one of several "blackline" shiners-*Notropis* species which are superficially very similar and have a prominent black lateral band which extends from the tail and on to the snout (e.g. Blacknose, Blackchin, and Pugnose shiners). These species are sensitive to environmental change and thus all threatened by decreases in water clarity and aquatic vegetation and excessive loading of nutrients and pesticides.

Evaluation

There is evidence of decline in many waterbodies where the Bridle Shiner was formerly more abundant, particularly in the rivers of Québec. Factors which appear to be causing the decline of the Bridle Shiner may include decreases in water clarity and removal and/or change in species composition of the aquatic macrophyte community. Water quality deterioration may also have had an impact in urbanized and industrialized areas. Populations in Lac St-Pierre and the Lac St-Pierre archipelago appear to be relatively stable. The population in the Thousand Islands region of both Ontario and New York seems to have increased since the 1970s. Increase in Zebra Mussel populations has increased water clarity which would presumably have a beneficial effect on Bridle Shiner populations. Many areas such as Lac Memphrémagog, la Baie Missisquoi tributaries, Lac St-Paul and several sites in Ontario have not been adequately sampled since the 1960s and 1970s and it is not possible to determine its current status in these areas.

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The Status of the Mira River Population of Lake Whitefish, *Coregonus clupeaformis*, in Canada*

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A unique and possibly genetically distinct population of Lake Whitefish is found in the Mira River and its tributary the Salmon River, Cape Breton Island, Nova Scotia. The Mira River population of Lake Whitefish is another interesting example of the plasticity that can be expressed within the *Coregonus clupeaformis* 'species complex'. Previously, it was thought that the Mira River population became established as a result of introductions of Lake Whitefish stock originating from the Great Lakes. Recent genetic studies indicate, however, that it is most closely related to the Acadian geographic race of Lake Whitefish (found only in Maine, Gaspé peninsula of Québec, New Brunswick and Nova Scotia), suggesting that the Mira River population may in fact be indigenous. Unfortunately, genetic studies conducted to date have not been at a sufficient level of resolution to confirm whether the Mira River population has diverged sufficiently to be considered a genetically discrete or distinct population. The Mira River population of Lake Whitefish is probably indigenous, differs morphologically from other Lake Whitefish populations in Nova Scotia and is geographically isolated from other populations in eastern North America. Therefore further genetic study at a sufficient level of resolution to verify whether the population is an evolutionarily significant unit is warranted.

Key Words: Lake Whitefish. Corégone de la rivière Mira, *Coregonus clupeaformis*, Mira River, Salmon River, Cape Breton Island, Nova Scotia, Canada, endangered species

The population of Lake Whitefish (Corégone de la rivière Mira), *Coregonus clupeaformis*, (Mitchell 1818), that occurs in the Mira River and its tributary the Salmon River, Cape Breton Island, Nova Scotia was identified as a potentially genetically discrete stock during studies of morphometric variation in whitefish populations from the Canadian Maritime provinces (Edge 1987). Lake Whitefish from the Mira River area exhibit distinctive characteristics for the species, particularly unusually low lateral line scale counts and low gill raker counts (Edge 1987; Edge et al. 1991).

The Lake Whitefish has been shown to exhibit a wide range of phenotypic and genotypic variation across North America (Koelz 1931; Lindsey et al. 1970; Scott and Crossman 1973; Ihssen et al. 1981), which has resulted in considerable taxonomic confusion. In recognition of the systematic problems resulting from the immense amount of ecological and morphological plasticity within the species, distinctive populations are often referred to as part of the Lake Whitefish "species complex".

Recognition of the threatened Lake Simcoe Whitefish, *Coregonus clupeaformis* spp. (Evans et al. 1988) and the rare Squanga Whitefish, *Coregonus* sp., which occurs sympatrically with other Lake Whitefish populations in four lakes (Bodaly et al.

1988), as distinct provide precedents for consideration of protection for other distinct populations of Lake Whitefish within Canada. A distinct population can be defined as a group of interbreeding individuals with similar gene frequencies (Li 1976). Such unique, genetically distinct populations represent evolutionary significant units of biodiversity that warrant identification and protection.

Recent genetic evidence suggests that the population of Lake Whitefish found in the Mira River area should be reevaluated, possibly in the context of a larger, evolutionarily distinct, Acadian geographic race¹, of Lake Whitefish (Bernatchez 1995; Bernatchez and Dodson 1990; Bernatchez and Dodson 1991; Bernatchez et al. 1991; Bodaly et al. 1992).

Description

The population of Lake Whitefish found in the Mira (Figure 1) and Salmon Rivers (subsequently referred to as the Mira River population) has unusu-

¹The Acadian geographic race and the Atlantic or Mississippi-Missouri (Atlantic) geographic race are genetically distinct stocks of the Lake Whitefish, *Coregonus clupeaformis*. They should not be confused with the endemic Atlantic Whitefish, *Coregonus huntsmani* [formerly *C. canadensis*], a distinct species that has also been referred to by the common name Acadian Whitefish in a previous COSEWIC report. In this report naming follows the accepted common and scientific names used by the American Fisheries Society in Robins et al. (1991).

*Reviewed and approved by COSEWIC April 1999, status assigned Indeterminate

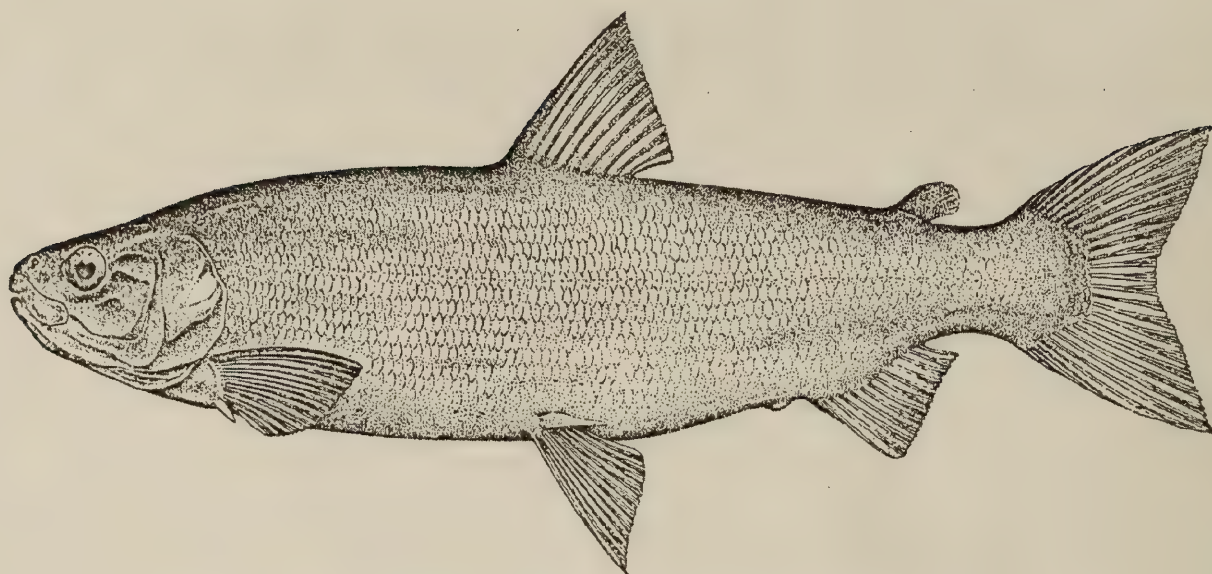


FIGURE 1. Mira River Whitefish (drawing by D. Brammall, courtesy Don McAllister).

ally low lateral line scale counts (Mira River 64–75, mean 70.1; Salmon River mean 68.0) and low gill raker counts (Mira River 20–24, mean 22.6; Salmon River mean 23.2) (Edge 1987; Edge et al. 1991). For Canadian populations of Lake Whitefish, lateral line scale counts reportedly range from 70 to 97 and gill raker counts range from 19 to 33 with seldom fewer than 22 in eastern Canada (Scott and Crossman 1973).

Many adults collected from the Mira River are characteristically large, robust and have a different external appearance from other Lake Whitefish in Nova Scotia (John Gilhen; Nova Scotia Museum of Natural History, Halifax, Nova Scotia; personal communication).

For a detailed description of the Lake Whitefish in Canada, refer to Scott and Crossman (1973). Overall coloration of the Lake Whitefish in Canada is silvery, grey or greenish with darker grey, greenish, light brown or dark brown back, becoming silvery on the sides and silvery or white below. The mouth is predominantly inferior and overhung by the snout, usually with weak teeth on the lingual plate and there are also teeth on the dentary in young fish but these are absent in adult specimens. Nuptial tubercles are present in both sexes, although they are fewer on females and more developed on males. Average length of adults in Canada is 38 cm total length but species can attain up to 73 cm in length.

Considerable confusion over Lake Whitefish and Atlantic Whitefish, *Coregonus huntsmani*, has led to previous mis-identifications of the two species in Nova Scotia. Mouth shape, lateral line scales and presence or absence of teeth in adults are often good distinguishing characteristics (Edge 1987; Scott and Crossman 1973). Atlantic Whitefish differ from Lake Whitefish in generally having more lateral line scales (91 to 100), mouth usually terminal with small

well-developed teeth on premaxillaries, palatine and vomer in adults, and teeth on tongue at all sizes (Scott and Scott 1988). With respect to mouth shape, Atlantic Whitefish tend to have a rounder snout profile and a more terminal mouth whereas Lake Whitefish tend to have an inferior mouth overhung by a more pointed snout. However, considerable variation in these characters has been reported for whitefish of both taxa from Nova Scotia (Edge 1987; Edge et al. 1991).

Edge et al. (1991) suggested that the best diagnostic character to reliably distinguish Atlantic Whitefish from Lake Whitefish in the Maritimes is vertebral number, which ranges between 64 and 67 for Atlantic Whitefish and 58 and 64 for Lake Whitefish. Location of capture may also help to identify the endemic Atlantic Whitefish, since it has an extremely limited and disjunct distribution in southern Nova Scotia. The Atlantic Whitefish has only been reported from the Tuskent River, vicinity of the Tuskent River in the Annis River (a tributary), Yarmouth Harbour (Yarmouth County), Halls Harbour (Kings County), off Wedgeport; as well as in Milipsigate, Minamkeak and Hebb Lakes, Petite Rivière watershed, (Lunenburg County), (ROM and CMN collection data; Scott and Crossman 1973; Scott and Scott 1988; Edge et al. 1991). A comparison of characters of Atlantic Whitefish, Lake Whitefish and Mira River Whitefish are presented in Table 1.

Taxonomic Status

A study of variation in *Coregonus* sp. from the Maritimes suggested that the Mira and Salmon River population of Lake Whitefish is a potentially genetically distinct stock in eastern North America. With unusually low lateral line scale counts and low gill raker counts and can be distinguished using

TABLE 1. A Comparison Of Characters Of Atlantic Whitefish, Lake Whitefish in Canada, and Mira River Population Of Lake Whitefish.

Characters	Atlantic Whitefish	Lake Whitefish in Canada	Mira River Population of Lake Whitefish
Gill Rakers	23–27, usually 25 or 26	19–33	20–24 (mean 22.6)
Branchiostegal Rays	6–9	8–10	(mean 8.9)
Dorsal Rays	10–12	11–13	(mean 13.9)
Anal Rays	9–12	10–14	(mean 14.9)
Pelvic Rays	11 or 12	11, sometimes 12	(mean 12.0)
Pectoral Rays	15 or 16	14–17	(mean 16.6)
Lateral Line	91–100	70–97	64–75 (mean 70.1)
Scales			
Pyloric caeca		140–222	
Vertebra	63 or 64	54–64	(mean 60.5)

canonical variates analysis of morphometric data (Edge 1987). Yet in a subsequent study of meristic and morphometric variation between the Lake Whitefish and the Atlantic Whitefish from the Maritimes, Edge et al. (1991) concluded that; while it was possible to readily distinguish the Atlantic Whitefish from the morphological variation found within the Lake Whitefish species complex, no statistically significant morphological basis was found for recognizing any Lake Whitefish population from the Maritimes region as taxonomically distinct from other Maritimes populations.

However, morphometric analysis is not a definitive method of identifying genetically different populations in studies of relationships of Lake Whitefish (except at the species level) because, like other members of the subfamily Coregoninae, whitefish exhibit a large degree of morphological plasticity (Imhof 1977). Therefore, morphometric analysis of Lake Whitefish populations cannot be relied upon to illustrate whether there are significant genetic differences among populations. Although differences in gill rakers (in this case counts, but in others length) and other meristic and morphometric features may often reflect genetic differences, variation in the latter can also occur in a relatively short time period through environmental modification (Lindsey 1981). Laboratory reared progeny of Lake Whitefish reared at different temperatures had fewer gill rakers than their parents (Todd 1997).

Scott and Crossman (1964) looked at variation that occurred in Lake Whitefish populations 75 years after being introduced to Hogans Pond (47°35'N, 52°51'W), Newfoundland, from stock that originated from Lake Erie, Ontario. Gill raker counts from Hogans Pond Lake Whitefish were higher than those reported for Lake Erie, although only a very small sample of fish taken from Hogans Pond were analyzed. Similarly, Loch (1974) studied induced phenotypic changes in Lake Whitefish by comparing

second generation stock transplanted to Lyons Lake (49°44'N., 95°10'W.), Manitoba, with parental stock. Although gill raker number and lateral line scale counts were essentially constant, gill raker length was significantly different. He also found differences in other meristic and morphological characters, as well as in electrophoretic phenotype frequencies of isozymes of GPDH.

Populations of Lake Whitefish that feed on planktonic organisms and terrestrial insects tend to have a greater number of longer gill rakers than benthic feeding stocks (Lindsey 1981). Large differences in gill raker number and length often occur between sympatric pairs of Lake Whitefish with different ecological niches. Sympatric pairs tend to be reproductively isolated from each other and exhibit different protein allele frequencies. Yet sympatric pairs have not diverged as much genetically as the different geographic races of Lake Whitefish where there is no evidence of reproductive isolation or sympatric coexistence (Bodaly et al. 1992). In the geographic races there are instead many instances of introgression among the different races (Foote et al. 1992). However, unlike sympatric pairs, the geographic races of Lake Whitefish have diverged little in ecological and morphological traits (Bodaly et al. 1992).

Molecular genetic studies indicate that there are at least four (possibly five) geographic races of Lake Whitefish in North America — Nahanni, Berring, Mississippi-Missouri (Atlantic) and Acadian — which have origins in different Wisconsinan glacial refuges (Bernatchez and Dodson 1994; Bernatchez et al. 1991; Bodaly et al. 1992). Lake Whitefish found in the northeastern United States and eastern Canada are from two geographic races. They may be part of;

- (a) an Atlantic race proposed by (Bernatchez and Dodson 1991)[said to be found only in parts of Maine and southern Quebec and originating from an Atlantic glacial refugium], or the Mississippi-Missouri (Atlantic) race, and

(b) the Acadian race (Bodaly et al. 1992).

The Acadian race, to which the Mira River population reportedly belongs, is present in the northeastern United States in Maine, and in eastern Canada in the Gaspé peninsula of Québec, New Brunswick and Nova Scotia (Bodaly et al. 1992). The Acadian race presumably survived Wisconsinan glaciation in the Northeastern Banks refugium (Schmidt 1986), although there are other areas that have been suggested as possible refugia including the area around the present-day Magdalen Islands, Gulf of St. Lawrence.

The Mira River population is genetically most similar to other populations of Lake Whitefish that belong to the Acadian race (Bernatchez and Dodson 1991), which suggests that it may be native. Although some genetic divergence from the parental stock could possibly have occurred in the approximately 100 years since Lake Whitefish were introduced to Cape Breton Island, it would not be expected to be as great as the genetic differences expressed in races with origins in different glacial refugia during the Wisconsin glaciation. If the Mira River population exists only as the result of previous introductions of stocks that reportedly originated from the Great Lakes region it would be expected to exhibit greater genetic similarity to other members of the Mississippi-Missouri race.

Edge (1987) provides a detailed discussion of whether Lake Whitefish populations in Nova Scotia are entirely the result of previous introductions or are native. (Refer to Distribution section for information on Lake Whitefish introductions in Nova Scotia). It has also been suggested that some Lake Whitefish introduced into the Maritimes region around the turn of the century may have come from stocks taken from areas in New Brunswick or Maine which belong to the Acadian race. However, some early natural history accounts suggest that at least some of the existing populations may be native to this region (Edge 1987).

Another consideration that will shed light on the evolutionary history of Lake Whitefish in Nova Scotia is whether the species would have been able to naturally disperse from the hypothesized refugia after the last glacial period.

The Wisconsin glaciation ended between 12 000 and 10 000 years ago. Possibly a strip of unglaciated land or a series of islands on the outer continental shelf connected Nova Scotia to New England during the last glacial ice advance. Native freshwater species probably dispersed to Nova Scotia from this refugium since the retreat of the last ice sheet. Movement from one watershed to another was probably as a result of river capture or the freshening of coastal waters by the melting ice sheet which enabled freshwater species to move around the coast from one river to another. Species with some degree of tolerance to salt water, including Lake Whitefish,

may have been able to move from one river system to another via estuaries. (Davis and Browne 1998).

Nova Scotia has a relatively depauperate freshwater fish fauna with only 17 species considered to be native, fewer in Cape Breton and in northern Cape Breton Island there are no purely freshwater species. (Davis and Browne 1998). Low diversity of freshwater fish species in parts of Nova Scotia suggests that there were impediments to dispersal after the last glacial period and may be a reflection of the lack of freshwater colonization routes. Perhaps in some areas, only species with tolerance to salt water were able to move from one river system to another via estuaries (Davis and Browne 1998).

Deglaciation of lowland areas in the southeastern part of Cape Breton Island has been estimated to have occurred at about 13 000 years ago. In the northern upland areas of Cape Breton deglaciation probably occurred much later, with successive readvances of ice possibly reoccurring until approximately 10 000 years ago (Roland 1982). The lack of freshwater species in the northern part of Cape Breton Island may be accounted for by the later retreat of the ice sheet there.

Considerable morphological and meristic variation has been shown among populations of Lake Whitefish in the Maritimes region (Edge et al. 1991). Apparently, the Mira River population has been known from the Mira River area for generations (J. Gilhen; personal communication). It is not known whether the species occurs there as a result of previous unauthorized introductions or whether it may have arrived as a result of post-glacial dispersal and it has not been shown whether the Mira River population represents a unique genetic form. To resolve these phylogenetic relationships, it is necessary to combine morphometrics, molecular genetics and geological history, bearing in mind that each of these methods may result in conflicting phylogenetic hypotheses for coregonids (Sajdak and Phillips 1997).

Distribution

Lake Whitefish have been reported from Atlantic coastal watersheds west throughout most of Canada and parts of the northern United States (Figure 2) to British Columbia, Yukon Territory and Alaska (Scott and Crossman 1973; Lee et al. 1980). In the United States, they have been introduced into parts of Montana, Washington and reportedly also in the Adirondacks region with fish from Labrador, Canada (Smith 1985).

In Canada, populations are found in most large lakes and rivers, from Nova Scotia, New Brunswick, and Labrador, west throughout Quebec, Ontario including the Great Lakes, coastal waters of Hudson Bay, throughout Manitoba, Saskatchewan (especially in the north), Alberta, British Columbia, and generally distributed throughout both Territories (Scott and Crossman 1973).



FIGURE 2. Distribution of Lake Whitefish, *Coregonus clupeaformis*, in North America [from Scott and Crossman (1973) by permission].

Lake Whitefish have been introduced widely in Canada, including parts of insular Newfoundland, as a forage fish and in attempts to establish commercial fisheries (Scott and Crossman 1973). In Nova Scotia, early attempts to introduce Lake Whitefish (alleged to be from the Great Lakes) around 1877 were reportedly unsuccessful (Piers 1927). Ultimately, over 24 million Great Lakes Lake Whitefish fry were planted in 22 lakes in 8 counties in Nova Scotia between 1890 and 1901 (Semple 1973, from Annual Reports of the Department of Marine and Fisheries).

In Cape Breton Island, Lake Whitefish were apparently only stocked in Lake Ainslie (46°08'N, 61°11'W) and Lake O'Law Brook (46°20'N, 61°01'W), Inverness County (Edge 1987). Evidently the stocking attempts in Cape Breton Island were unsuccessful as no Lake Whitefish were found in Lake Ainslie and Lake O'Law Brook during field survey's conducted during the early 1980s (Edge 1987).

Currently, disjunct populations of Lake Whitefish are now found throughout Nova Scotia including the Mira River population in Cape Breton Island, although whether any are native populations or the result of previous stocking attempts is unclear. Until

the early 1920s no indigenous form of the genus *Coregonus* had been reported from Nova Scotia even though *Coregonus clupeaformis* was known to occur in Québec, Labrador and New Brunswick (Piers 1927). However, ichthyological surveys were virtually unknown prior to this time. Subsequently, whitefish, presumed to be Lake Whitefish, were reported from a number of disjunct locations in Nova Scotia. Many of the localities where Lake Whitefish have been found are in locations for which there are no records of early introductions, although it is possible that there were unrecorded or unauthorized introductions or that the original stocks dispersed and became established elsewhere (Edge 1987). Historical stocking records are considered to be unreliable and it is possible that stocking was more widespread that records indicate.

Some of the early collections of whitefish in Nova Scotia, thought to be Lake Whitefish, were actually the endemic Atlantic Whitefish, *Coregonus huntsmani*. Errors in identification resulted from confusion that existed prior to the recognition of the Atlantic Whitefish as a distinct species (Scott 1967).

Lake Whitefish populations are now found in Guysborough, Lunenburg, Queens, Yarmouth, and

Cape Breton Counties and have been reported from Annapolis, Halifax and Richmond Counties (Semple 1973; Edge 1987).

Although not normally associated with brackish and saltwater habitats, the Lake Whitefish has been recorded along the east coast of James Bay, shores of Hudson Bay, and in brackish water adjacent to Ungava Bay (Scott and Scott 1988). It also occurs in brackish water in Arctic Ocean drainages of the Northwest Territories (Scott and Crossman 1973). The species also may occur in Atlantic coastal drainages but reports of this species in salt water off the Atlantic Coast of Canada have generally been in reference to the Atlantic Whitefish, with the exception of one Lake Whitefish specimen caught in salt water off Black's Harbour, New Brunswick (Scott and Scott 1988).

The Mira River population of Lake Whitefish has been found only in the Mira River (46°02'N 59°58'W) and the Salmon River (45°55'N 60°18'W), Cape Breton Island, Nova Scotia (Figure 3). The Salmon River is a tributary of the Mira River. Collection sites reported by Edge (1987) were approximately 10 km apart.

The population of Lake Whitefish from the Mira and Salmon Rivers is geographically separated from other extant populations of this species in the rest of Nova Scotia by St. Georges Bay and the Strait of Canso. Although Lake Whitefish are tolerant of salt water and may sometimes act in an anadromous fashion, they rarely stray too far from their rivers of

origin and therefore would not likely disperse to other areas through marine waters. Despite relatively extensive sampling including field surveys conducted during 1982, 1983 and 1985, Lake Whitefish have not been found at any other localities in Cape Breton Island, particularly the Lake Ainslie and Lake O'Law Brook localities where they were reportedly stocked in the later part of the last century (Edge 1987).

The Mira and Salmon Rivers are approximately 94 km and 62 km (measured "as the crow flies" from the mouth of each river) southeast of the Ainslie Lake location and are separated from it by Bras D'Or Lake, a large inland sea with surface salinity between 20.0 to 25.0 ppt but no significant tide (*Natural History of Nova Scotia*). It is unlikely that Bras D'Or Lake is a barrier to dispersal of Lake Whitefish since populations of the species elsewhere are tolerant of brackish and salt water. However, the lack of freshwater connections and opposite direction of flow between the watersheds to the northwest of Bras D'Or Lake (i.e., Lake Ainslie and Lake O'Law Brook) and those to the southeast (i.e., Mira and Salmon Rivers) would impede dispersal of Lake Whitefish. Lake Ainslie empties into the Southwest Margaree River (46°20'N, 61°05') and Lake O'Law Brook empties into the Northeast Margaree River (46°20'N 61°05'W) which at their confluence flow northward into the Gulf of St. Lawrence at Margaree Harbour (46°26'N, 61°06'W). Although the Salmon River flows in a northeast direction parallel to Bras



FIGURE 3. Location of Capture of Mira River Lake Whitefish Populations in Cape Breton Island, Nova Scotia.

D'Or Lake for part of its course, at its most northern part it turns and flows south away from Bras D'Or Lake and into the Mira River (Roland 1982). The Mira River empties into the Atlantic Ocean at Mira Bay on the southeastern coast of Cape Breton Island.

It is possible that transfer between these two watersheds could have been assisted by human intervention. Lake Whitefish are a favoured food species and therefore are sought extensively on both a commercial and recreational basis in many parts of Canada (Scott and Crossman 1973). There are numerous instances where fish species have apparently been transferred through unauthorized and often unreported human actions. In Nova Scotia, unauthorized introductions of other freshwater fish species such as Chain Pickerel, *Esox niger*, and Smallmouth Bass, *Micropterus dolomieu*, have had profoundly negative effects on trout populations already marginalized by environmental degradation (R. Bancroft, Nova Scotia Department of Fisheries and Aquaculture, Pictou, Nova Scotia; personal communication).

Protection

The Mira River population Whitefish has not been formally recognized as a distinct species or evolutionarily significant population unit, has not been designated any status and it receives no specific protection at this time. The status of other unique populations of whitefish have been evaluated by the Committee on the Status of Wildlife in Canada (COSEWIC) with the result that the Lake Simcoe Whitefish, *Coregonus clupeaformis* ssp. is listed as threatened and the Squanga Whitefish, *Coregonus* sp. is listed as vulnerable by COSEWIC. However, COSEWIC status by itself does not currently confer special protection.

Other populations of *Coregonus clupeaformis* receive no special protection in Canada other than the general habitat protection afforded by the Federal *Fisheries Act*.

The Lake Whitefish does not receive protection in Nova Scotia. For recreational fishing, there is no catch and possession limit and no closed season, except that no one is permitted to angle in inland (non-tidal) waters unless the season is open for salmon, trout or Smallmouth Bass (Nova Scotia 1998 Angling Summary of Regulations). On the other hand, the endangered Atlantic Whitefish, *Coregonus huntsmani* is a prohibited species under the Maritime Provinces Fishery Regulations promulgated under the *Fisheries Act*. Atlantic Whitefish habitat is protected in the Petite Rivière watershed through designation as a Protected Water Area since Minamkeak, Milipsigate and Hebb Lakes provide the domestic and industrial water supply to the town of Bridgewater (Edge 1984 from Lunenburg County District Planning Commission 1980).

In the United States, the Lake Whitefish is protected only in Illinois (Johnson 1987) but Lake Whitefish are found only in some northern parts of the United States, where the species is at the extreme southern limit of its range.

Population Size and Trends

The size of the Mira River population of Lake Whitefish has not been estimated. Over a hundred specimens have been collected in the Mira and Salmon Rivers but only sporadic sampling has occurred over the past 20 years. The relative abundance of Mira River population was considered to be above average for whitefish from the Canadian Maritimes based solely on a comparison of the rate of catch in gill nets (Edge 1987); however the study was not specifically designed to estimate population size.

The Mira River population population may have been large enough to support a small local fishery since historically they were reportedly caught in nets set in the Mira River. Generally in Nova Scotia, Lake Whitefish are not considered to be an important species in recreational or commercial fishing (Semple 1973), probably a result of generally low population numbers. The lack of early accounts of the presence of Lake Whitefish in Nova Scotia waters (Piers 1927) suggests that population numbers may have always been low or alternatively that current populations are primarily or entirely the result of introductions. Largely overlooked in the past, Lake Whitefish are now known from several watersheds in Nova Scotia and are more common than previously recognized (Edge 1987). Lake Whitefish have eluded capture in other areas. For example, despite extensive angling for Brook Trout, Lake Whitefish had never been recorded from Kerr Lake, New Brunswick, until they were taken in gill nets (Smith 1952).

Habitat

Very little is known about the habitat of the Mira River population of Lake Whitefish. The Mira River is generally very wide (up to 1.5 km) with little current until approximately 3 km from the mouth. There the river suddenly becomes more narrow and flows through a channel (with a steep embankment on the north shore) into Mira Bay. Collection data from a field input sheet indicates that Lake Whitefish from the Mira River were caught upstream in a gill net set 150 m offshore at depths of between 12 to 25 m during July (collection data; Canadian Museum of Nature). The Mira River at the collection site is approximately a kilometer wide with almost imperceptible current and the habitat is more similar to a large lake. Although considerably narrower, the Salmon River meanders through lowland areas (less than 100 m above sea level).

The Lake Whitefish is a cool water species (Scott and Crossman 1973). In lakes in the southern part of its range, it occupies cooler waters in the hypolimnion during the summer months (Scott and Crossman 1973). As reported by Smith (1952) for Kerr Lake, New Brunswick, Lake Whitefish were taken in summer in gill nets set approximately 7.5 m deep. Lake stratification was present and Lake Whitefish appeared to avoid oxygen depleted waters and shallow warmer waters.

Lake Whitefish may be tolerant of a relatively wide range of habitats in Canada as indicated by collection records (unpublished habitat data, ROM). They have been found in water with currents ranging from still to swift and a wide range of water temperatures up to a maximum of 22°C. However, cooler temperatures are required for successful incubation of Lake Whitefish eggs. As determined under experimental conditions, normal development occurs over a temperature range of 0.5°C to 6.1°C whereas at higher temperatures an increase in mortality and abnormality of eggs occurs (Scott and Crossman 1973). At temperatures greater than 10°C only a very small percentage (1%) of eggs survive (Scott and Crossman 1973).

Reported substrates at collection sites include rock, rubble, gravel sand, silt, clay, mud, muck and detritus in areas where aquatic vegetation ranged from absent to some submerged macrophytes present. Many of the differences in habitat among collection sites are probably related to capture during different life history stages, food availability or food preferences of individual stocks.

General Biology

Reproductive Capability

No information on Lake Whitefish reproduction in the Mira and Salmon Rivers is currently available. Generally throughout Canada, Lake Whitefish spawning occurs in the fall or winter on sand, gravel or stones on reefs in lakes or streams and no redds are prepared (McAllister and Crossman 1973). In the Great Lakes region, spawning usually occurs in November and December but in more northern parts of Canada, spawning is usually earlier in September to October. Differences in time of spawning appear to be temperature dependent with first spawning usually commencing after water temperatures drop below 8°C and peak spawning occurring at even lower temperatures (Scott and Crossman 1973).

In Nova Scotia, Lake Whitefish spawning was observed in Scots Lake (44°47'N, 63°11'W) (formerly Scotch Pond), Petpeswick Lake area [formerly Petpeswick River] (44°45'N, 63°11'W), Halifax County, by Semple (1973). Spawning commenced in early December after water temperatures had dropped to 4.5°C and probably continued into late December or possibly early January.

Spawning adults generally move to shallow areas near shore and spawn in water less than 7.6 m deep (Scott and Crossman 1973; Smith 1985). It appears that Lake Whitefish resident in streams remain there to spawn and similarly lake resident fish probably do not generally move into tributary streams to spawn. From observations of Lake Whitefish in Kerr Lake, New Brunswick, Smith (1952) suggests that spawning occurred in the lake since none were captured in trap nets set at the mouths of tributary streams during late summer and fall. It is possible that the fish moved upstream to spawn after nets were removed, since spawning in areas of Nova Scotia with similar climate occurs later, sometimes in late fall or early winter (Semple 1973). However, specimens of both sexes observed in July had well developed gonads suggesting they would have spawned earlier in the fall. In Nova Scotia, no mature ripe fish were captured until just over a week prior to commencement of spawning in mid-December (Semple 1973).

For Lake Whitefish from Scots Lake (Scotch Pond), Nova Scotia, average fecundity was determined to be 15 698 eggs/kg of fish (Semple 1973). Fecundity was not consistently related to length or weight for the 22 fish sampled. Fecundity was lower than generally reported in other parts of Canada except for Hogans Pond, Newfoundland where it was determined to be only 11 650 eggs/kg (Chen 1967).

Semple (1973) determined maturity and size of Lake Whitefish during the spawning period in Scots Lake. Average fork length of spawning adults was 21 cm and maximum length was 26 cm. All fish greater than 18 cm FL were mature and members of both sexes began maturing at lengths greater than 16 cm FL. According to age estimates, 80% of all fish were mature at age 1, 90% at age 2 and all were mature at age 3. Age at maturity in Scots Lake is less than that reported from other parts of Canada but similar to that of Lake Whitefish in Maine. Sex composition was approximately 1:1 male to female ratio.

The rate of growth of Lake Whitefish in Canada is generally quite rapid and they generally reach a commercially acceptable size of over 1 kg between 3 and 10 yrs (Scott and Crossman 1973). In Scots Lake, the largest fish (age 6) weighed only 0.2 kg. The average weight for all Lake Whitefish captured in the study was 117 g. (Semple 1973), suggesting the rate of growth was relatively slow in Scots Lake.

Species Movements

Movements are related to both spawning and temperature preferences. Deeper cooler hypolimnetic waters in lakes are preferred during summer (Scott and Crossman 1973). Lake Whitefish often move into shallow areas in spring (Smith 1985). During the fall breeding season spawning adults generally move inshore to shallow water areas over hard, stony

bottom or sand (Scott and Crossman 1973). Young whitefish may remain in shallow water areas where they feed primarily on plankton until early summer when they generally move into deeper water with increasing dependence on benthic organisms (Scott and Crossman 1973). Lake Whitefish may remain in deeper offshore waters during the warmer summer months and then migrate inshore when water temperatures decline). In Lake Erie, Ohio, they were observed moving into inshore reefs when water temperatures dropped to 10°C and swimming near the surface on windless days (Trautman 1981).

One study suggests that Lake Whitefish may, at least occasionally, travel considerable distances. An individual from the Great Lakes was reportedly recaptured 150 miles from where it was tagged (Budd 1957). In northern parts of Canada, Lake Whitefish may run to sea (McAllister and Crossman 1973). There is a possibility that Mira River Lake Whitefish may travel out to sea in Mira Bay, perhaps to feed (J. Gilhen; personal communication), although this has not yet been confirmed through analysis of stomach contents or by checking scales for evidence of anadromy.

Behaviour/Adaptability

Edge (1987) studied the diet of Lake Whitefish in the Canadian Maritimes and found that there was considerable variation between populations, ranging from selection of almost exclusively planktonic organisms to almost exclusively benthic organisms. This is consistent with what has been observed in other parts of Canada. Planktonic organisms and even terrestrial insects form the major part of the diet of some populations of Lake Whitefish (Scott and Crossman 1973). Most Lake Whitefish in Nova Scotia, including the Mira River population, apparently fed primarily on benthic organisms. Mira River Lake Whitefish stomach contents were found to contain the following food items in order of abundance: Amphipoda, sphaeriid clams, insect larvae, Cladocera, Gastropoda, Hydracarina, and Ostracoda (Edge 1987). Small sample size may account for the lack of other food items, such as terrestrial insects or fish, found in stomach contents (Edge 1987) or it may be related to timing of collections, food preferences or seasonal variability in food selection.

Fish species found in association with Lake Whitefish in Nova Scotia included Atlantic salmon, *Salmo salar*, Rainbow Smelt, *Osmerus mordax*, White Sucker, *Catostomus commersoni*, Brown Bullhead, *Ameiurus nebulosus*, White Perch, *Morone americana*, Yellow Perch, *Perca flavescens*, American Eel, *Anguilla rostrata*, and *Alosa* sp. (Edge 1987). In the Mira River, Lake Whitefish were found in association with Atlantic Salmon, Rainbow Smelt, White Perch, White Sucker in gill net catches (Edge 1987). The Alewife, *Alosa pseudoharengus*, was also captured in gill nets in the Mira River.

Limiting Factors

Human Disturbance

Mira River Lake Whitefish populations have possibly been exploited. Historically, nets were set in the Mira River specifically to catch this species (D. MacLean; personal communication). Currently, unauthorized gill netting for Lake Whitefish in the Mira River appears to be a problem. Recently, specimens caught illegally were confiscated and these are now held in museum collections (J. Gilhen; personal communication). High levels of unemployment in the region may be contributing to the exploitation of fish stocks. There are several large population centres (i.e., Sydney, Glace Bay) within approximately 20 km of the mouth of the Mira River.

Other whitefish populations are known to be exploited in Nova Scotia. Edge (1984) proposed that populations of the endangered Atlantic Whitefish were being depleted by severe overfishing and poaching.

Perhaps populations of Lake Whitefish are also being depleted as a result of angling, either when specifically targeted or through incidental catches when targeting other species. Unlimited recreational fishing for Lake Whitefish is permitted throughout Nova Scotia when the open season for Atlantic Salmon, trout (Rainbow Trout, *Oncorhynchus mykiss*, Brown Trout, *Salmo trutta*, Brook Trout, *Salvelinus fontinalis*, Lake Trout, *Salvelinus namaycush*) and Smallmouth Bass, is in effect in particular waters. However, there is only conflicting anecdotal information available regarding possible captures of Lake Whitefish from either the Mira or Salmon Rivers in recent years. There is very little information available since the Lake Whitefish is not considered an important species throughout most of Nova Scotia. This is the opposite of what occurs in many other parts of Canada where Lake Whitefish is a major recreational and commercial species.

Creel census catch statistics for Nova Scotia do not include Lake Whitefish; however, the Mira River area of Cape Breton Island appears to be one of the more heavily fished areas of Nova Scotia (ASE Consultants Inc. 1995). Cape Breton County represents 11% of the total angling effort (measured in days fished) for 18 counties in Nova Scotia, the majority of effort from resident anglers (Nova Scotia Department of Fisheries and Aquaculture 1997). Greater angling effort only occurs in two other Counties, Halifax and Guysborough which account for 15.2% and 11.6% respectively. The majority of inland fishing effort in Cape Breton County is directed primarily towards Brook Trout and Rainbow Trout followed by Smelt, Brown Trout, White Perch and Yellow Perch (Nova Scotia Department of Fisheries and Aquaculture 1997).

Habitat Loss/Environmental Contamination

Since there is so little known about the habitat

preference of the Mira River population, it difficult to determine if habitat degradation is occurring or affecting populations in the Mira and Salmon Rivers. Similarly, there is very little information regarding Lake Whitefish populations in Nova Scotia. However, the related Atlantic Whitefish was probably once a more widespread or wide ranging species in coastal waters of northeastern North America and populations have probably been reduced by the effects of deforestation, dam building, over-exploitation and introductions on aquatic ecosystems (W. B. Scott, Huntsman Marine Science Centre, St. Andrews, New Brunswick; personal communication). Assuming some of the current Lake Whitefish populations in Nova Scotia are native, they may also have been reduced by similar ecological factors. Evans et al. (1988) suggest that decline of Lake Simcoe Whitefish may have been partly related to environmental factors such as eutrophication and contaminants. However, these factors are probably not significantly affecting populations in the Mira and Salmon Rivers.

In many parts of Nova Scotia, particularly in southern and southwestern areas, acidification of surface waters is a problem that has affected fisheries, especially salmonids. Edge (1984) expressed concern over increasing acidification of rivers affecting survival of Atlantic Whitefish. Although the Cape Breton Island highland area is considered to be sensitive to the effects of acid rain, surface waters throughout Cape Breton are greater than pH 5.4 (Davis and Browne 1998) and therefore it is unlikely that acidification is affecting fish productivity in the Mira River area.

Predation

There are no known reports of predation by other species on Lake Whitefish in Nova Scotia. Throughout Canada, a number of fish species reportedly prey on Lake Whitefish (Scott and Crossman 1973) but of these only Lake Trout and Yellow Perch, *Perca flavescens*, are found in Nova Scotia. Lake Whitefish also reportedly consume their own eggs (Scott and Crossman 1973). American Eel, *Anguilla rostrata*, may also prey on Lake Whitefish. American Eels are important predators of young salmon, trout and other fish including cyprinids (Scott and Crossman 1973), although there are no known reports of predation on Lake Whitefish.

Parasites

No parasites have been reported from Lake Whitefish found in the Mira River. Lake Whitefish elsewhere in Canada are host to a large number of parasitic organisms (Hoffman 1967; Lawler 1970; Scott and Crossman 1973). In Kerr Lake, New Brunswick, Lake Whitefish were reportedly being heavily scared by eels (Smith 1952), possibly a reference to Sea Lamprey, *Petromyzon marinus*.

Special Significance

The Mira River Whitefish is known only from the Mira and Salmon Rivers, Cape Breton Island. Whether it represents a genetically discrete stock of Lake Whitefish has not been adequately determined and it is unclear whether it occurs in the area as a result of previous stocking efforts or has arrived there as a result of post-glacial dispersal. In any case, it represents an interesting example of the plasticity of members of the *Coregonus clupeaformis* "species complex".

In other parts of Canada, Lake Whitefish are considered a valuable recreational and commercial freshwater species. However, they are susceptible to environmental deterioration and exploitation. Generally throughout Nova Scotia, Lake Whitefish are not considered to be an important recreational or commercial fish, except perhaps in southeastern Cape Breton Island, where there appears to be a limited fishery for Lake Whitefish from the Mira River.

Evaluation

If the Mira River population of Lake Whitefish is determined to be an indigenous and discrete stock of Lake Whitefish, then it would warrant some form of protection because it is geographically and reproductively isolated, has an extremely limited distribution, and has unique characteristics. Unless further genetic studies indicate differently, no emendation of the scientific name is suggested or required since distinctness is probably at the population level and not representative of a new subspecies or species.

There is insufficient scientific information available for status designation at this time.

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Updated Status Report on the Endangered Atlantic Whitefish, *Coregonus huntsmani**

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The Atlantic Whitefish, *Coregonus huntsmani*, is an endemic Canadian species known only from the Tusket and Petite Rivière watersheds in southwestern Nova Scotia. The species is anadromous in the Tusket River and its tributary the Annis River. It has declined drastically in these rivers as a result of factors related to a hydro-electric dam, acidification, overfishing and poaching. The construction of a hydro-electric dam on the Tusket River has prevented Atlantic Whitefish from migrating upstream to spawn and exposed them to poachers in fish ladders. More recently the spread of Chain Pickerel, *Esox niger*, has contributed to the decline of Atlantic Whitefish in the Annis River. The decline in the Tusket River watershed has continued since the last COSEWIC report in 1983, although the report of an Atlantic Whitefish in the Tusket River in 1996 may indicate a remnant population still exists. Atlantic Whitefish have been regularly caught by anglers in the Petite Rivière watershed since the late 1800s although population trends are uncertain. Atlantic Whitefish are landlocked in three lakes in this watershed and there appears to be a small population in the lower Petite Rivière. The Atlantic Whitefish populations in the Petite Rivière lakes may be threatened by acidification and the spread of non-indigenous fish predators like Smallmouth Bass. Field studies in 1982–1985 provided some knowledge of the habitat and biology of Atlantic Whitefish although the ecological requirements of the species are still poorly known. The Atlantic Whitefish Conservation and Recovery Team was created in 1999 and is actively investigating requirements to conserve the species. The Atlantic Whitefish is threatened with imminent extinction and its status should remain as endangered.

Key Words: *Coregoninae*, whitefish, Atlantic Whitefish, Corégone atlantique, *Coregonus huntsmani*, rare and endangered fishes, Tusket River watershed, Petite Riviere watershed, Nova Scotia.

The status of the Atlantic Whitefish, *Coregonus huntsmani*,¹ was first reviewed following a field survey conducted in Nova Scotia in the fall of 1982 (Edge 1984). This field survey found Atlantic Whitefish surviving in the Annis River, Yarmouth County, and in three lakes in the Petite Rivière watershed, Lunenburg Co. The species appeared to be threatened with extinction and the Committee on the Status of Endangered Wildlife in Canada designated the Atlantic Whitefish as an endangered species in 1983 (McAllister et al. 1985; Campbell 1997).

The status of the Atlantic Whitefish has not been updated since its original designation as an endangered species in 1983. The systematics, distribution, ecology and zoogeography of the Atlantic Whitefish were studied in subsequent years, including additional field studies of its habitat in the Petite Rivière lakes during 1983–85 (Edge 1987). The results of these field studies and other more recent information obtained from fisherman, residents and the Atlantic Whitefish Conservation & Recovery Team (AWCRT) are summarized in this update on the status of the Atlantic Whitefish.

Description

The Atlantic Whitefish, *Coregonus huntsmani*, is a member of the whitefish subfamily (*Coregoninae*), trout family (*Salmonidae*) (Figure 1). It has silvery sides, a white belly, and a back that is dark bluish-black or dark green. The Atlantic Whitefish can be readily distinguished from most other trout-like fishes by its larger more prominent scales. The species is described by Scott and Scott (1988) as having more than 90 scales in the lateral line, a terminal mouth (lower jaw and upper jaw equal) and small but well

*Reviewed and approved by COSEWIC November 2000, status assigned — Endangered, no change.

¹The species was first described as the Atlantic Whitefish, *Coregonus canadensis*, by Scott (1967). This species name was subsequently found to be preoccupied by D. E. McAllister and the replacement name *C. huntsmani* was proposed by Scott (1987). A number of publications have referred to the species by the more geographically precise common name Acadian rather than Atlantic (e.g., Edge, 1984; McAllister et al., 1985; McAllister, 1990; Edge et al., 1991; Bernatchez et al., 1991; Coad, 1995). However, scientists, government officials, and residents from the Petite Rivière and Tusket River communities met in Halifax, Nova Scotia in September 1999 to discuss the status of the species and concluded the species should be referred to by the common name Atlantic Whitefish as outlined in Robins et al. (1991).



FIGURE 1. The Atlantic Whitefish, *Coregonus huntsmani* (by permission of Don E. McAllister). Drawn by P. Drukker Bramwell, 1984.

developed teeth on the tongue, and premaxillaries, vomer, palatines, and lower jaw bones at all sizes. Edge et al. (1991) found Atlantic Whitefish to have 25–29 gill rakers.

The Atlantic Whitefish has been confused in the past with the Lake Whitefish, *Coregonus clupeaformis*, which is also found in Nova Scotia. However, the Atlantic Whitefish and Lake Whitefish have been clearly distinguished based upon both morphological and genetic characteristics. Scott and Scott (1988) indicate that Lake Whitefish lack teeth on premaxillaries, palatines and vomer bones except in juvenile fish under 100mm. Edge et al. (1991) found the best distinguishing characteristics for Atlantic Whitefish were its more terminal mouth and a higher number of vertebrae (64–67, \bar{x} = 65.3) than Lake Whitefish from the Canadian Maritime Provinces and the U.S. State of Maine. The Lake Whitefish from this area were found to have a subterminal mouth and 58–64 (\bar{x} = 60.6) vertebrae. The number of lateral line scales was also useful in distinguishing 93% of the whitefish specimens examined (Figure 2). Atlantic Whitefish had a higher number of lateral line scales (88–100, \bar{x} = 93.8) than Lake Whitefish (63–95, \bar{x} = 76.6). Other morphological characteristics for distinguishing Atlantic Whitefish and Lake Whitefish, were provided by Edge et al. (1991) including comparative photographs. Genetic characteristics have also proven useful for distinguishing Atlantic Whitefish from Lake Whitefish. Bernatchez et al. (1991) found Atlantic Whitefish possessed a unique isozyme and a mitochondrial DNA genotype different from that of Lake Whitefish which indicated that these two species are genetically distinct.

Distribution

North American and Canadian Range

The Atlantic Whitefish is an endemic Canadian species known only from southwestern Nova Scotia

(Figure 3). Field studies conducted in 1982, 1983 and 1985 found the Atlantic Whitefish restricted to two disjunct watersheds: the Tusket River watershed, Yarmouth County, and the Petite Rivière watershed, Lunenburg County (Edge 1987). The populations in the Tusket River, and its tributary the Annis River, are anadromous and known to venture into seawater. The populations in the Petite Rivière watershed occur in three lakes (Mina-mkeak, Milipsigate, and Hebb lakes) (Figure 4). Atlantic Whitefish have been angled in Fancy Lake although it is not known whether there is a resident population there. What appears to be a small anadromous population exists in the lower Petite Rivière.

Populations of the Atlantic Whitefish have not been reported outside the Tusket and Petite Rivière watersheds despite extensive commercial and recreational fisheries in fresh and coastal waters throughout Nova Scotia. In addition, extensive province-wide fish surveys have failed to identify new Atlantic Whitefish populations outside these two watersheds. For example, fish populations were surveyed in 744 lakes throughout Nova Scotia between 1964 and 1981 by the federal Department of Fisheries and Oceans, the Canadian Wildlife Service, and the Nova Scotia Department of Lands and Forests (Alexander et al. 1986). While 14 lakes were found to contain Lake Whitefish, there were no reports of Atlantic Whitefish. Similarly, fish surveys conducted for the Atlantic Whitefish throughout Nova Scotia in 1982 and 1983 found four lakes containing Lake Whitefish, but Atlantic Whitefish were not found outside of the Annis and Petite Rivière watersheds (Edge 1987).

At one time, the Atlantic Whitefish may have occurred in the Medway River watershed. Mina-mkeak Lake, the uppermost lake containing Atlantic Whitefish in the Petite Rivière watershed, previously

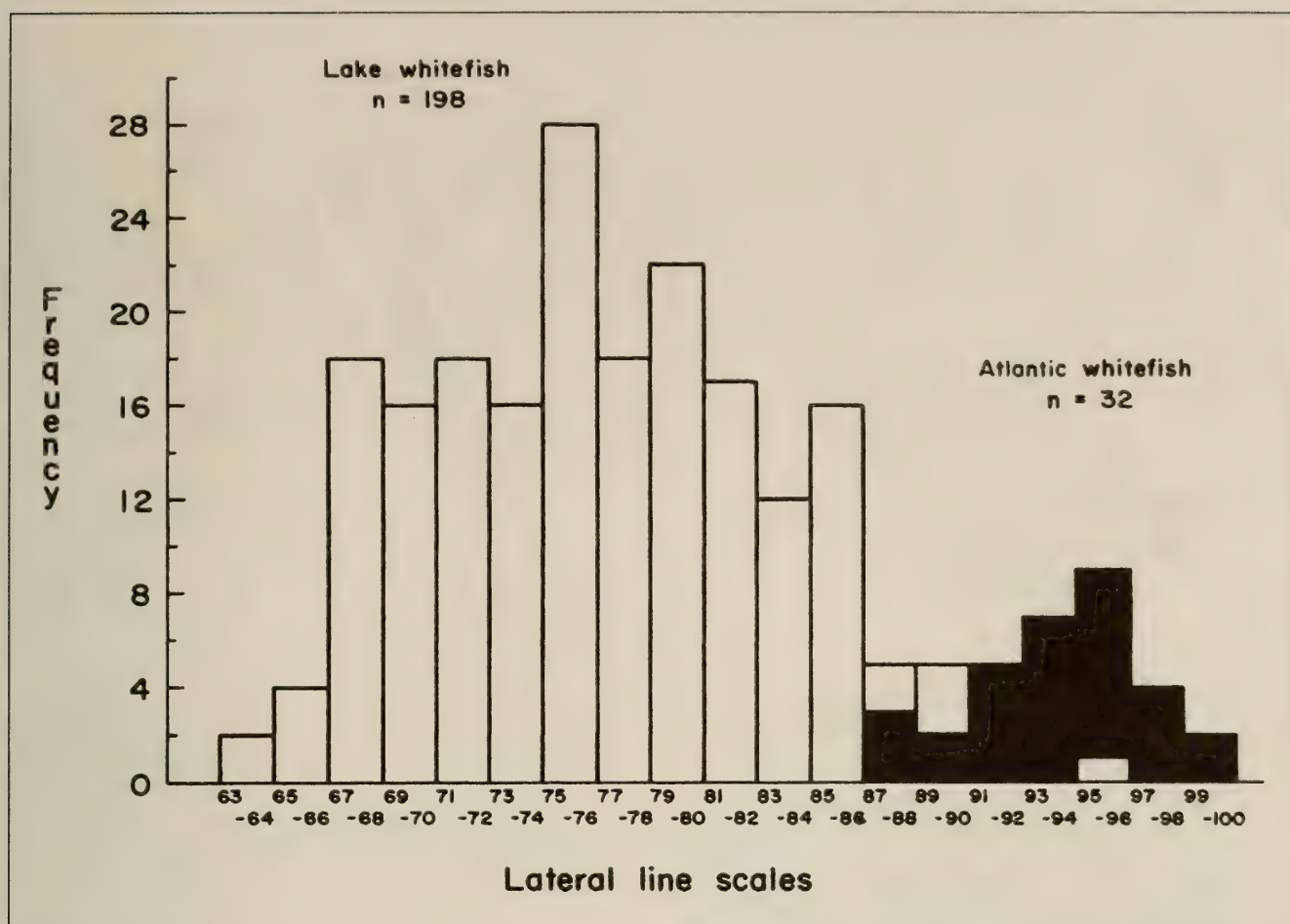


FIGURE 2. The frequency of lateral line scale counts on Atlantic Whitefish and Lake Whitefish specimens from the Canadian Maritime Provinces and the State of Maine, U.S.A.

flowed into the Medway River. Dynamite was used to create an outflow from Minamkeak Lake into Milipsigate Lake around 1905, and the original outflow of Minamkeak Lake into the Medway River watershed was blocked. It is not known whether the population of Atlantic Whitefish in Minamkeak Lake occurred there before this diversion or whether it is the result of upstream dispersal from Milipsigate Lake.

Atlantic Whitefish specimens have been caught on five occasions outside the Tusket and Petite Rivière watersheds. A specimen was caught in seawater on 12 June 1940, in Yarmouth Harbour, Yarmouth County, and another on 31 May 1958, in a herring weir at Halls Harbour, Kings County. Two specimens are also reported to have been caught in full seawater at the mouth of the Sissiboo River, Digby County on 8 September 1919 (Scott and Scott 1988). More recently, an Atlantic Whitefish specimen was caught in the smelt fishery in the Lahave River estuary, Lunenburg County in February, 1995 (D.R. Bell, in litt., February 1997) and another one was caught there on 24 May 1997 (A. Hebda, personal communication, March 1998). The Lahave River watershed is adjacent to the Petite Rivière

watershed. The isolated nature of all these captures as well as the migratory habits and salt water tolerance of Atlantic Whitefish would suggest these specimens were likely strays from the Tusket and Petite Rivière watersheds.

While the Atlantic Whitefish appears to be restricted to the Tusket and Petite Rivière watersheds, it should be noted that populations of whitefish in the Maritimes Region have gone undetected for long periods of time. Smith (1952) found a population of Lake Whitefish in Kerr Lake, New Brunswick, that was poorly known among local anglers and residents. Similarly, by setting gillnets in the deeper waters of Nova Scotian lakes, Edge (1987) found Lake Whitefish populations that were unknown to local anglers, residents or fishery officers. Deep water habitat preferences, small population sizes, and poor angling potential may enable whitefish populations to evade detection. This should be borne in mind for future lake surveys for Atlantic Whitefish, since Alexander et al. (1986) indicated that a limitation of their provincial lake surveys was the likely undersampling of deeper waters (> 10m) because of the difficulty of setting gillnets in these habitats.



FIGURE 3. Distribution of the Atlantic Whitefish in Nova Scotia. The Tusket, Annis and Petite Rivière watersheds known to support Atlantic Whitefish are shown as well as four records (●) outside these watersheds where specimens have been captured. 1 = Hall's Harbour, Kings County, 1958; 2 = Sissiboo River mouth, Digby County, 1919; 3 = Yarmouth Harbour, Yarmouth County, 1940; 4 = Lehave River mouth, Lunenburg County, 1995/97.

Habitat

Definition

(1) *Tusket River Watershed*. Very little is known about the habitat requirements of the Atlantic Whitefish in the Tusket River watershed. The Atlantic Whitefish is known to be anadromous in the Tusket River and its tributary, the Annis River. The Tusket River watershed provides an extensive estuarine habitat for the Atlantic Whitefish and the species has been commonly caught in these brackish waters in the past. Atlantic Whitefish are known to venture into full seawater and specimens have been caught off Wedgeport, Yarmouth County, at a salinity of 31 ppt (Scott and Scott 1988).

Atlantic Whitefish are not known to enter fresh water much above the influence of tidal waters in the Tusket and Annis rivers. In the past, Atlantic Whitefish have been captured in winter through the ice in Lake Vaughn just above the Tusket River dam (Patrick Patten, personal communication, March 2000). While the spawning and nursery requirements for Atlantic Whitefish are unknown, Smith (1962) indicated the Tusket River provided over 138 000 m² of spawning areas and over 668 000 m² of nursery areas for Atlantic Salmon. A potential annual return

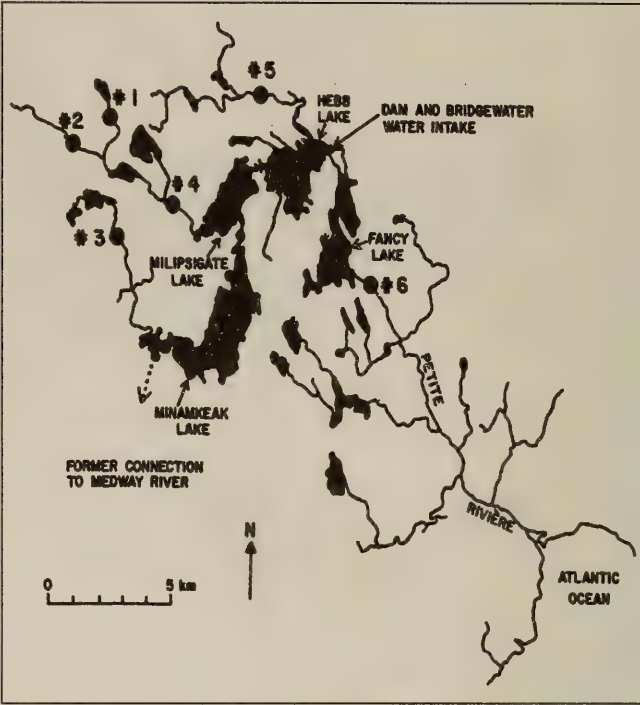


FIGURE 4. The Petite Rivière watershed, Lunenburg County, Nova Scotia, showing water chemistry sampling stations in 1983-85 (1 – St. George Brook; 2 – Still Brook; 3 – Frederick Lake outlet; 4 – Birch Brook; 5 – Wildcat Creek; 6 – Petite Rivière at Conquerall Mills).

of between 1600 and 3200 adult salmon was considered possible from the river although the annual run was considered very small by the 1960s.

The Tusket River is quite acidic compared to many other rivers in Nova Scotia (Farmer et al. 1980; Watt et al. 1983). Farmer et al. (1980) surveyed the Tusket River at Gavelton in 1979–1980 and found pH values from 4.55 to 4.85. They considered the Tusket River to be one of seven mainland Nova Scotian rivers unsuitable for the successful reproduction of Atlantic Salmon. They also suggested that a small salmon population had probably survived in the Tusket River because water quality had remained acceptable in the Carleton River tributary. Watt et al. (1983) reported the mean pH of the Tusket River to be 4.8 in 1980–81 (4.6 in the East Branch).

Water samples collected from the Tusket River area in 1983 and 1984 were analyzed by the Department of Fisheries and Oceans laboratory in Halifax (Edge 1987). These water samples were obtained from the Annis River and Tusket River (at Lake Vaughn reservoir) just above the influence of tidal waters in September 1983, and January 1984. In September 1983 when Atlantic Whitefish would begin migrating into fresh water, the pH of the Tusket River at Lake Vaughn was 5.23 and the pH of the Annis River was 6.05. In January 1984, the pH at Lake Vaughn was 4.59 and the pH of the

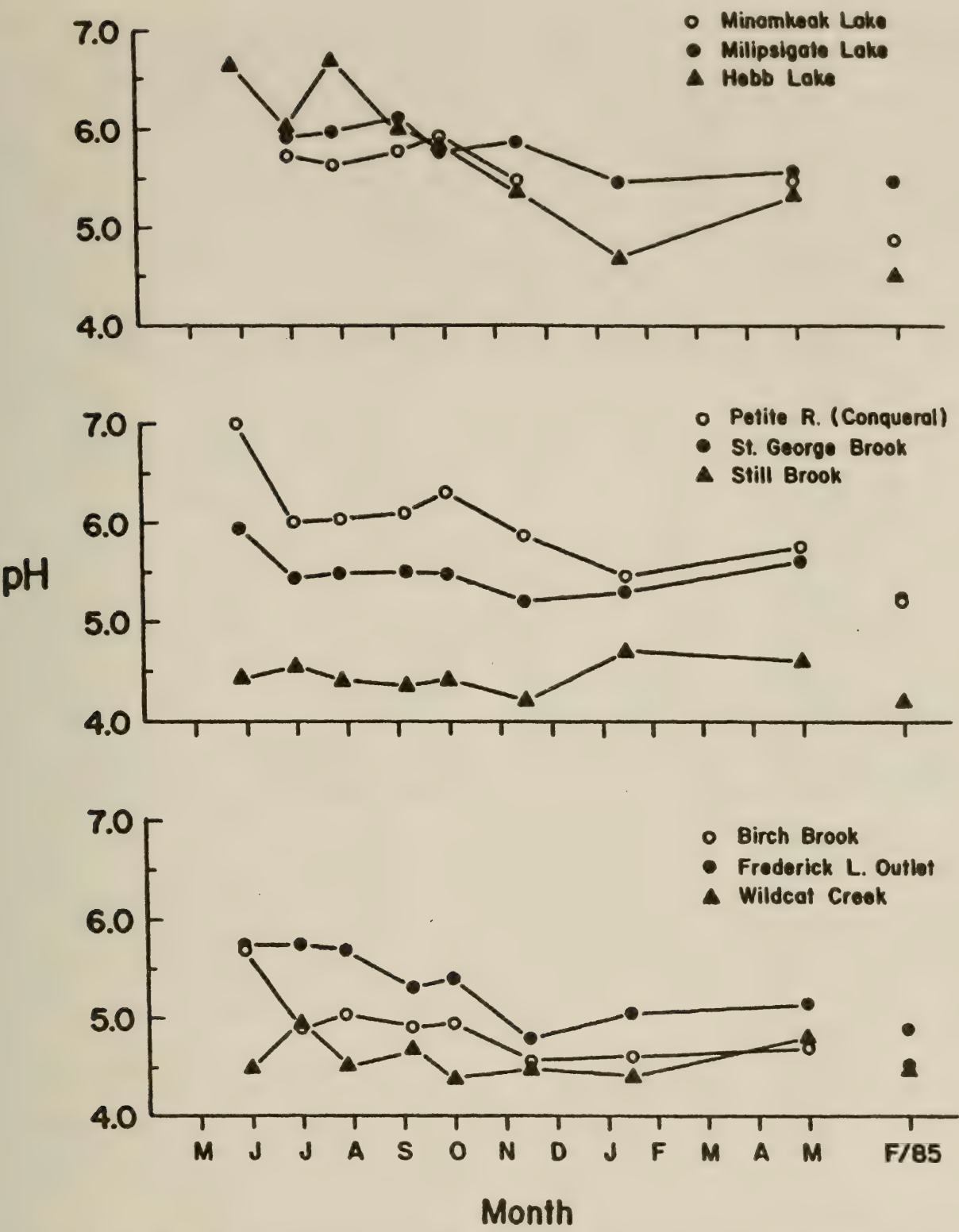


FIGURE 5. Seasonal water pH variation throughout the Petite Rivière watershed, Lunenburg County, Nova Scotia from 1983 to 1985. See Figure 4 for water sampling locations.

Annis River was 5.02. pH data from the Tusket River were collected around 1980 in the Carleton tributary and 1995–96 in the main Tusket branch (Wilsons Bridge) (data from ENVIRODAT (Atlantic Database Water Chemistry Data). These data indicate the average annual pH in the Carleton River based upon 11 monthly samples was 5.65 in 1980.

The average annual pH in the main Tusket branch based upon 12 monthly samples was 4.68 in 1995, and 4.64 based upon seven monthly samples in 1996. Low pH values like those in the Tusket River east main branch have been shown to be detrimental to the survival of Atlantic Salmon (Lacroix and Townsend 1987), and they have probably had an adverse

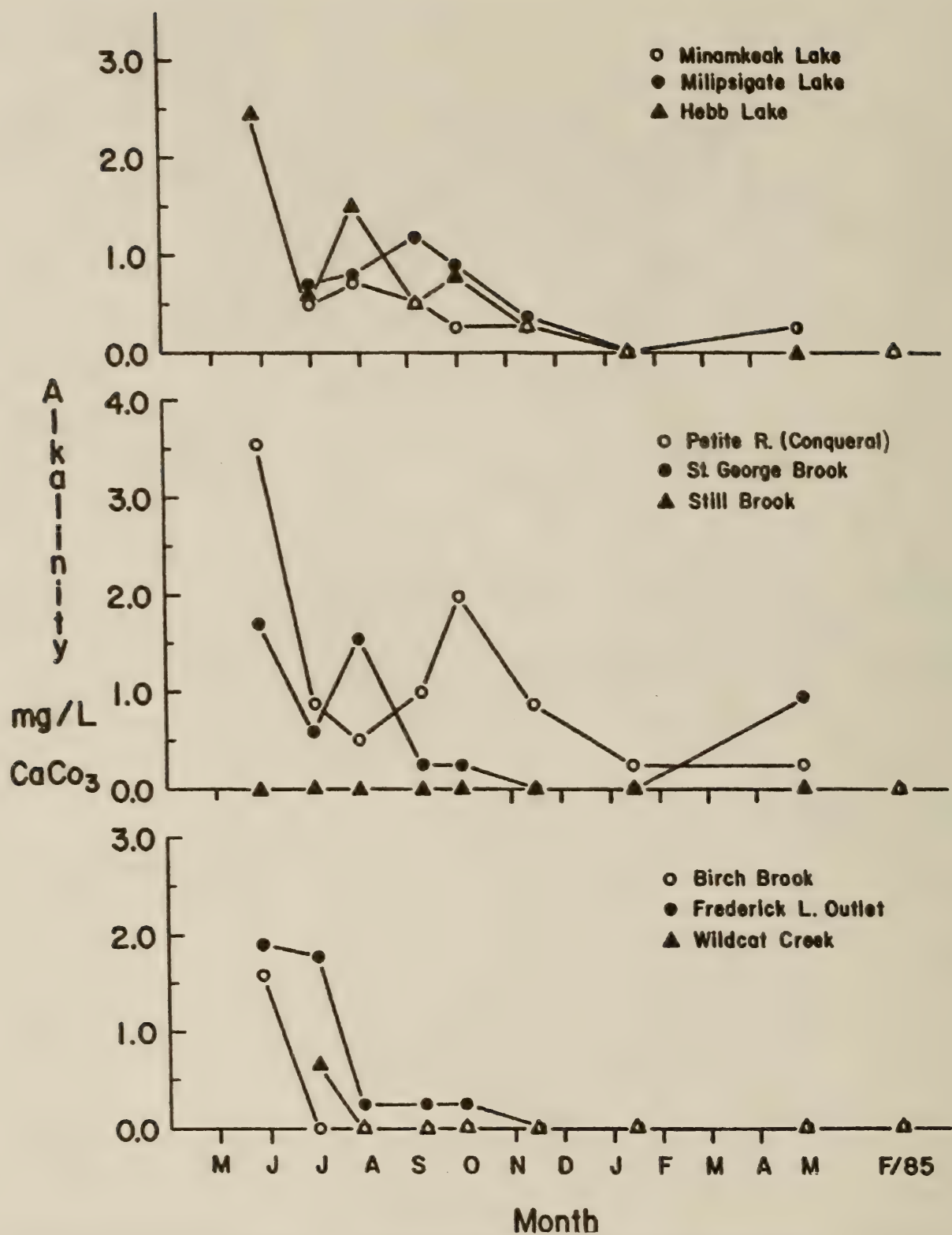


FIGURE 6. Seasonal water alkalinity (mg/l of CaCO₃) variation throughout the Petite Rivière watershed, Lunenburg County, Nova Scotia from 1983 to 1985. See Figure 4 for water sampling locations.

impact on the ability of Atlantic Whitefish to reproduce in the Tuskent River.

(2) *Petite Rivière Watershed.* The Atlantic Whitefish has adapted to a completely freshwater habitat in lakes within the Petite Rivière watershed. The area around the Petite Rivière was first settled in the 1600s and the subsequent building of mill dams along the river was extensive (Dunfield 1985). While these mill dams would have obstructed the river to varying degrees, the construction of a hydro-electric dam at the foot of Hebb Lake as early as 1901 effectively blocked any upstream migration of fishes. There is no record of fish ladders or any

means to allow fish passage upstream at this point since construction of the dam. One of the earliest saw mills in the Petite watershed was formerly located at the site. If Atlantic Whitefish in the Petite Rivière lakes were once anadromous, these populations have had no access from the sea since at least 1901. At present, dams without fish ladders obstruct the Petite Rivière at the outlets of Minamkeak, Milipsigate and Hebb lakes. A power dam built around 1939 at Conqueral Mills below Fancy Lake was breached in 1977.

The Petite Rivière watershed drains an area of about 233 square kilometers. Farms and a few small towns are found within the watershed, although forested areas predominate, particularly surrounding the lakes. A characteristic of the watershed is the abundance of bogs which impart a tea-colour to the water. Bathymetric surveys of Minamkeak, Milipsigate, and Hebb lakes indicated that these lakes had maximum depths in 1983 of 13 m, 16 m, and 14 m respectively, although much of the area of these lakes is more shallow. The lake bottoms are silt in the deeper water areas, whereas shoals and shoreline areas are rocky. A study of the temperature profile in Hebb Lake in 1983 indicated the warm water nature of this lake. While the lake did stratify to a degree during the summer, a typical coldwater hypolimnion was not present. The temperature at the bottom of the lake in May was 14°C, and it rose to almost 20°C by late August.

The Petite Rivière has been less affected by acidification than the Tusket River. Watt et al. (1983) indicated the river had a mean pH of 5.6 between 1980–81. Watt (1986) categorized the Petite Rivière as a river where Atlantic Salmon stocks had not yet been affected by acidification and where there was no sign of an impact of acidification on angling returns.

Water chemistry data were collected from the Petite Rivière watershed in 1983–84 and analyzed by the Department of Fisheries and Oceans laboratory in Halifax (Edge, 1987). The Petite Rivière showed a trend in seasonal pH variation similar to other rivers in Nova Scotia (Figure 5). pH was high over the spring and summer and then fell quickly in the fall to a midwinter pH minimum. pH also varied widely throughout the watershed such that while it was usually above 5.5 in the lower Petite Rivière at Conqueral, pH was rarely above 4.5 in Still Brook, a darkly coloured brook draining a bog area. The lakes within the Petite Rivière watershed usually had a pH above 5.0. During February 1985, however, pH values were recorded from Hebb and Minamkeak lakes as low as 4.5 and 4.8 respectively, indicating pH fluctuations which could adversely affect aquatic life. pH data from the lower Petite Rivière available from ENVIRODAT (Atlantic Database Water

Chemistry Data) indicate the average annual pH in the Petite Rivière based upon 11 monthly samples was 5.62 in 1985.

Alkalinity values, indicative of the buffering capacity of water, also varied considerably throughout the watershed (Figure 6). Alkalinity was usually detectable in the Petite Rivière at Conqueral whereas Still Brook lacked measurable alkalinity throughout the year. The Petite Rivière lakes had low alkalinity values (usually below 1.0 mg/l of CaCO_3), particularly over the winter, and alkalinity was not measurable in Minamkeak and Hebb lakes in February 1985. It remains uncertain how the Petite Rivière watershed will retain its buffering capacity to counter acidification.

An indication of habitat preferences of Atlantic Whitefish in the Petite Rivière lakes is provided by gillnet capture data (Table 1). Based upon catch per unit effort, Atlantic Whitefish were caught more than twice as often in surface waters compared to midwater or bottom habitats. This finding was in contrast to other fish species which were found to be more abundant near the bottom than in surface waters. Atlantic Whitefish caught at the surface comprised 27% of the catch of all fishes whereas midwater and bottom captures comprised 20% and 2%, respectively. Those Atlantic Whitefish caught near the bottom were almost invariably caught in the deeper parts of the lakes. Only 7% of the bottom catches of Atlantic Whitefish were made in gillnets set on the bottom at a depth of less than 8 m.

Habitat requirements for Atlantic Whitefish in the lower reaches of the Petite Rivière are poorly known. It is uncertain if this is a resident anadromous population or whether Atlantic Whitefish have continuously passed downstream over the Hebb Lake dam to the sea. While Atlantic Whitefish have been regularly caught over many years in the brackish waters of the Petite Rivière estuary, gaspereau fishermen from this area have not heard of captures in fresh water in the lower Petite Rivière nor in nearby seawaters (D. R. Bell, personal communication, 1997).

Trends

The Tusket River hydro-electric dam has significantly changed the habitat of the Atlantic Whitefish since it was built in 1929. It is uncertain what impact the current dam and associated fish ladders are having on any remaining Atlantic Whitefish. However, there continue to be concerns about inadequate waterflows in fish ladders during Atlantic Whitefish migration periods. There continues to be threat of habitat loss through acidification in both Tusket and Petite Rivière watersheds. In addition, the recent spread of Chain Pickerel in the Annis River and introduction of Smallmouth Bass into the Petite Rivière watershed have posed significant new threats to maintaining suitable

TABLE 1. Habitat preferences of Atlantic Whitefish and other fish species in the Petite Riviere lakes, Nova Scotia, expressed as number of specimens caught in gill nets.

habitat	gill net effort (hrs)	Fish species				
		<i>Coregonus huntsmani</i>	<i>Catostomus commersoni</i>	<i>Ameiurus nebulosis</i>	<i>Morone americana</i>	<i>Perca flavescens</i>
Fall 1982						
Surface	60	12	0	0	32	12
Midwater	48	3	1	0	6	7
Bottom < 8 m	85	1	68	9	129	7
Bottom > 8 m	115	8	64	5	270	40
Spring 1983						
Surface	12	5	0	1	0	0
Midwater	12	2	2	0	4	0
Bottom > 8 m	12	3	2	0	5	0
Summer 1983						
Bottom < 8 m	36	0	10	1	18	0
Bottom > 8 m	18	3	7	0	5	0
Total						
Surface	78	17	0	1	32	12
Midwater	60	5	3	0	10	7
Bottom < 8 m	121	1	78	10	147	7
Bottom > 8 m	145	14	76	5	280	42

habitat for Atlantic Whitefish. Any potential shoreline development or angling activities around the Petite Rivière lakes will require careful monitoring.

Protection/Ownership

The habitat of the Atlantic Whitefish in the Petite Rivière lakes is protected to some degree by provincial legislation. The town of Bridgewater (population 7248 in 1991) has received its water supply from Hebb Lake since the turn of the century and maintenance of water quality in the watershed has been a concern. The area surrounding Hebb Lake and Milipsigate Lake was designated a Protected Water Area under provisions of the Water Act in 1964. The area around Minamkeak was similarly designated in 1975. The Minamkeak Lake and Milipsigate-Hebb Lakes protected water areas cover approximately one half of the total watershed and protect against lakeshore development, recreational activities, and the dispersal of sewage, biocides or garbage near the lakes. In addition, the Petite Rivière Watershed Advisory Group has expressed a concern about ensuring the protection of Atlantic Whitefish in the watershed (Peter Oickle, Bridgewater, in litt., 1985). This group was created in 1977 by the Nova Scotia Department of Environment to advise the Province of Nova Scotia, the Town of Bridgewater, and the Municipality of the District of Lunenburg on problems and solutions to water quality, levels, and flows in the watersheds of Minamkeak Lake, Milipsigate Lake, Hebb Lake, Fancy Lake and the Petite Rivière system.

Biology
General

Many aspects of the general biology of Atlantic Whitefish are still poorly known. There has not been a growth study of Atlantic Whitefish, but anadromous specimens from the Tusket River are known to grow larger than the landlocked ones from the Petite Rivière watershed. Scott and Scott (1988) indicated that Atlantic Whitefish were reported by a fishery officer to have been as large as 3.63 kg in the Tusket River and that specimens caught in the Tusket River salmon trap in 1954 ranged from 0.45 to 2.27 kg according to local observers. A fisherman caught an Atlantic Whitefish wedged into an eel pot on the Annis River in the fall of 1981 that was about 2.5 kg and amongst the largest he had ever caught (Limon Earl, Lake Pleasant, personal communication, October 1982).

Anglers have reported Atlantic Whitefish specimens from the Petite Rivière lakes were usually 17.5 cm to 40 cm and from 0.57 kg to 0.68 kg although rare individuals as large as 45 cm have been caught (Piers 1927; Gilhen 1999). Atlantic Whitefish in the lower Petite Rivière appear to grow larger than the lake specimens. A gaspereau fisherman caught an Atlantic Whitefish in the estuary in May, 1996 that was about 50 cm in length and about 1.82 kg in weight (D. R. Bell, personal communication, 1997). The largest specimens studied by Edge (1987) from the Tusket and Petite Rivière watersheds were 507 mm and 317 mm in total length, respectively.

Reproduction

The exact spawning period and spawning locations for Atlantic Whitefish are not known. Atlantic Whitefish in the Tusket River probably spawn in the late fall or winter. A female specimen caught in the Annis River on 12 October 1982, when water temperature was 12° C, had well-developed ovaries but was not yet ready to spawn. A specimen caught at the Tusket River dam on 4 November 1967, also had well-developed gonads but was not ready to spawn. Adult specimens caught in the Tusket River on 24 May 1940, and 24 June 1966, had poorly developed gonads suggesting spawning had occurred.

Spawning probably takes place in the Petite Rivière lakes in the winter months. Atlantic Whitefish in Hebb Lake had not spawned as late as 13 November 1982 when water temperature was 10° C. The gonads of these specimens were well developed although the fish were not yet ready to spawn. Specimens caught in Hebb Lake on 22 May 1983, when water temperature was 14° C had much smaller gonads suggesting spawning had already occurred. Semple (1973) found Lake Whitefish from Scotch Pond, Nova Scotia, started to spawn on 10th December when water temperature had dropped to 4.5° C.

Very little information is available on the spawning behavior or early life history stages of the Atlantic Whitefish. Despite extensive fish surveys in the Petite Rivière lakes in the 1980s and many years of observations by fishermen in the Tusket and Petite Rivière watersheds, young Atlantic Whitefish were never noted. Gaspereau fisherman familiar with Atlantic Whitefish in the Annis River and the Petite Rivière have indicated they have never seen young Atlantic Whitefish (L. Earl, personal communication, 1983; D.R. Bell, personal communication, 1997). More recently, members of the Atlantic Whitefish Conservation and Recovery Team have reported observing juvenile fish in the Petite Rivière lakes in the spring of 2000.

Survival

There is no information available on survival of the Atlantic Whitefish. Young have rarely been reported and Atlantic Whitefish population age structures have not been studied. Little can be said about important factors affecting mortality or recruitment rates. The lack of ability to find young Atlantic Whitefish in field surveys in 1982–1983 could have been the result of recruitment failure, or more likely, inadequate sampling methods.

Physiology

There is no information on the physiology of the Atlantic Whitefish. Like some species of *Coregonus* occurring in coastal drainages of the Nearctic and Palearctic, it has a capacity to tolerate full seawater. It also appears to be able to tolerate relatively warm water conditions in the Petite Rivière lakes. Its ability

to tolerate low pH at different life history stages is unknown.

Movement

The Atlantic Whitefish is anadromous in the Tusket and Annis rivers. Scott and Scott (1988) indicated that the whitefish migrate upstream in the Tusket River in October and then downstream to the estuary in the spring. A former fishery officer in the Tusket River area indicated that Atlantic Whitefish move upstream to spawn from mid-September to early November, and then moved downstream to the sea about mid-February to late March, with a few stragglers in early April (Gilhen 1977). One fisherman on the Annis River called Atlantic Whitefish “frost fish” because they usually started to move into fresh water around the time of the first frost in the fall.

Atlantic Whitefish are not known much above the Lake Vaughn reservoir in the Tusket River or much upstream of the small Pleasant Lake on the Annis River, and thus do not appear to migrate much into fresh water. A fisherman on the Annis River indicated Atlantic Whitefish did not venture as far into fresh water as Atlantic Salmon, and that Atlantic Whitefish were not known to reach Salmon Lake on this river (Limon Earle, Pleasant Lake, October 1982, personal communication). Scott and Scott (1988) indicated that Atlantic Whitefish were often accompanied by Atlantic Salmon on their upstream migration in the Tusket River in the fall.

Atlantic Whitefish are known to move downstream in the Tusket River in the spring and venture well out of the estuary into full seawater. Specimens have been caught in seawater at Yarmouth Harbour, Hall's Harbour, and probably at the mouth of the Sissiboo River. Available capture records indicate that Atlantic Whitefish are at sea in coastal waters during summer months and suggest that they may disperse widely in the marine environment from the Tusket River. Although the movements of Atlantic Whitefish in seawater are not well known, people from the Tusket River area believed their movements were similar to Atlantic Salmon (W. B. Scott, in litt., 1965).

The Atlantic Whitefish populations in the Petite Rivière lakes are landlocked and it is not known whether they were anadromous at one time or not. There are no fish ladders around the dams at the outlets of Minamkeak, Milipsigate and Hebb lakes so upstream movements are probably restricted. The hydro-electric dam at the foot of Hebb Lake has effectively blocked any upstream migration of fish since its construction in 1901. While Atlantic Whitefish may be swept downstream from Hebb Lake, the dam precludes any upstream movements. It is unknown if the Atlantic Whitefish in the lower reaches of the Petite Rivière have a regular anadromous migration.

TABLE 2. Feeding preferences of Atlantic Whitefish and Lake Whitefish from Nova Scotia. Values expressed as per cent of the number of all food items eaten at each location.

Food item	Atlantic Whitefish				Lake Whitefish		
	Hebb Lake n=8	Milipsigate Lake n=6	Minamkeak Lake n=4	Tusket River n=10	Mira River n=12	Lake George n=14	Pringle Lake n=7
Cladocera	45.2	2.7	99.7	0	9.1	2.5	99.8
Isopoda	0	0	0	0.9	0	12.2	0
Amphipoda	0	0	0.1	0.3	32	15.3	0
Sphaeriid clam	0	0	0	0	25.4	14.6	0
Gastropoda	0	0	0	0	1.6	2.3	0
Fish	0	2.7	0	0.2	0	0	0
Insect larva	0	12.2	0.1	72.6	19.2	30.9	0.1
Insect nymph	1.3	2.7	0.06	24.6	0	1.4	0
Insect pupa	1.1	27.9	0	0	3.3	4.2	0.1
Insect adult	52.4	51.8	0	1.3	0	13.9	0
Other	0	0	0.04	0.1	9.4	2.7	0

The saltwater tolerance of Atlantic Whitefish and records of incidental captures outside the Tusket and Petite Rivière watersheds indicate there is some potential for movements between watersheds in Nova Scotia.

Nutritional and Interspecific Interactions

Atlantic Whitefish from the Tusket and Petite Rivière watersheds are known to feed upon a wide variety of food items based upon a stomach content analysis of collected specimens (Edge, 1987). Atlantic Whitefish captured in Hebb Lake had fed on many flying ants (Hymenoptera) while smaller specimens from Minamkeak had fed mostly on plankton (Cladocera). Atlantic Whitefish from Milipsigate Lake had fed most commonly on dragonfly nymphs (Odonata), although they had also eaten adult Hemiptera and beetles (Coleoptera), Cladocera, mayfly nymphs (Ephemeroptera), Diptera pupae and Banded Killifish (*Fundulus diaphanus*). Variation in stomach contents probably reflects the seasonal variation in available food items at the time the Atlantic Whitefish specimens had been caught.

The stomach contents of Atlantic Whitefish from the Tusket River differed from that of the Petite Rivière lake specimens. Diptera pupae were generally the most commonly occurring food item for Tusket River Atlantic Whitefish, although stonefly nymphs (Plecoptera), blackfly larvae (Simuliidae) and other diptera larvae were also commonly eaten. Some Tusket River specimens had ingested large numbers of stonefly nymphs and blackfly larvae. Those Atlantic Whitefish caught in brackish or salt water had been feeding upon shrimp (Decapoda), amphipods, and fish (*Ammodytes sp.*). Scott and Scott (1988) indicated that the stomachs of Atlantic Whitefish caught off Wedgeport in seawater were found to contain the remains of Atlantic Herring (*Clupea harengus*), periwinkles (*Littorina littorea*),

amphipods, decapods, and a few blades of eelgrass (*Zostera marina*). Atlantic herring remains were thought to have come from feeding on refuse from a nearby herring processing plant. Atlantic Whitefish captured in the Petite Rivière estuary have been reported to have been feeding upon amphipods and marine worms (D. R. Bell, personal communication, September 1999).

A comparison of the major food classes consumed by Atlantic Whitefish and Lake Whitefish found in Nova Scotia lakes is presented in Table 2. While there is considerable variation between populations within a species, there were notable differences between Atlantic and Lake Whitefish in Nova Scotia. Whereas Lake Whitefish commonly fed on molluscs, Atlantic Whitefish never fed on this food item in fresh water. Similarly Lake Whitefish often contained many amphipods and isopods whereas Atlantic Whitefish very rarely consumed these organisms. Atlantic Whitefish were found to feed more heavily on insects than Lake Whitefish, particularly Coleoptera and winged insects characteristic of surface waters. Atlantic Whitefish also fed on fish, unlike Lake Whitefish.

The data on gillnet capture and stomach contents indicate that Atlantic Whitefish commonly occur in surface waters in the Petite Rivière lakes. They rarely consumed typical benthic food items such as amphipods, isopods, and molluscs, but instead had fed upon plankton, fish and a variety of foods which had presumably fallen onto the surface or were perhaps taken above the water surface. These data appear consistent with behavioral reports about Atlantic Whitefish from anglers who have caught them with hooks baited with small minnows and with a fly usually before the fly touched the water (S. E. March, in litt., 1925).

There is little information about Atlantic White-

fish parasites. Atlantic Whitefish in the Petite Rivière estuary are reported to lack sea lice which are found on Atlantic Salmon in the same estuary (D.R. Bell, personal communication, September 1999).

Behaviour/Adaptability

Little is known about the behavior and adaptability of the Atlantic Whitefish. They have been reported to occur in schools in the Petite Rivière watershed lakes and they have been caught in swift currents by anglers using a hook baited with a worm or small minnow, or using a small artificial fly or tiny natural flies on very small baited hooks (Piers 1927). The Atlantic Whitefish would usually take the bait just below the surface in swift running water. They would take a fly from two to six inches above the water and occasionally on the surface. Anglers have described them as gamey fighters that, when hooked, almost always leap from the water until exhausted.

Some anglers have caught Atlantic Whitefish in the Petite Rivière lakes early in the spring as the ice was leaving, but considered it impossible to catch these fish after the ice was gone (D. R. Bell, in litt., 1997). In the lower Petite Rivière, a gaspereau fisherman has indicated he had never heard of an Atlantic Whitefish entering a net during daylight hours in the estuary; only after dusk could they be caught (D. R. Bell, in litt., 1997).

Very little is known about the adaptability of Atlantic Whitefish and requirements for maintaining the species in captivity for re-stocking purposes. Some preliminary efforts to maintain Atlantic Whitefish at a hatchery were not successful. Four Atlantic Whitefish were captured alive from gillnets set in Hebb Lake in November 1982. These four specimens were transported to a Department of Fisheries and Oceans fish hatchery on the Mersey River within two hours of removal from gillnets. They were transported in barrels containing water from Hebb Lake that were aerated using a scuba tank. The four Atlantic Whitefish were placed in a holding tank (8 foot diameter) at the hatchery. Two Atlantic Whitefish died the following day, while a third survived for several days. The last specimen survived over the winter months but died in the spring probably because it would not eat hatchery food (T. Goff, personal communication). More recently in 2000, the Atlantic Whitefish Conservation and Recovery Team transported whitefish to the Mersey River fish hatchery to renew captive breeding efforts with some success. More understanding of the biology and reproductive requirements of Atlantic Whitefish will be needed to develop a successful hatchery program for the species.

Population Size and Trends

Atlantic Whitefish have been known to fishermen in the Tusknet River, Annis River, and Petite Rivière

watersheds for many years. The populations of Atlantic Whitefish in the lakes and lower reaches of the Petite Rivière watershed appear to be small based upon available habitat. There is little information on population trends. The numbers of Atlantic Whitefish in the Tusknet River, and its tributary the Annis River, have declined drastically in recent decades and it is possible the species may have disappeared from this watershed. There is insufficient information available at this time to enable accurate estimates of the population sizes and trends of Atlantic Whitefish in the Tusknet and Petite Rivière watersheds.

(1) Tusknet River

The Atlantic Whitefish was once very abundant in the Tusknet River watershed (Gilhen 1977; Scott and Scott, 1988). Large numbers of these whitefish were known to migrate up the river during anadromous migrations in the months of October and November, and anglers on the river and in Wedgeport and Yarmouth harbours considered them abundant. Prior to 1940, it was not uncommon for a gaspereau fisherman on the Tusknet River to accidentally catch 200 specimens in a gaspereau net (Gilhen 1977). Scott and Scott (1988) indicated that an Atlantic Salmon trap located on the Tusknet River in 1954 caught the following numbers of Atlantic Whitefish moving upstream that year:

18 to 24 th October	– 24 whitefish;
25 to 31 st October	– 47 whitefish;
1 to 7 th November	– 15 whitefish.

The construction of a hydro-electric dam on the Tusknet River at Tusknet falls in 1929 appears to have had a significant impact on the abundance of the Atlantic Whitefish. The Tusknet River dam is near the limit of the influence of high tide, and before construction of the dam, was an area of fast flowing rapids just below a lake that supported good fishing (Erskine 1971). The Tusknet River power facility is composed of two dams; the hydro-electric dam which generates electricity and, about 1 km to the east, a holding dam which helps to control the water levels in the Lake Vaughn head pond reservoir. When the hydro-electric dam was originally built, there was no means to deter fish from migrating through the sluices of the dam and, as a result, many Atlantic Whitefish were probably killed by the turbine blades (Gilhen 1977).

Studies conducted at the Tusknet River hydro-electric dam in the autumn of 1960 and also 1961 indicated that salmon and gaspereau passing through the turbines could suffer considerable mortality from abrasion, impact or internal haemorrhaging from pressure changes. The average mortality rate for young salmon descending through the turbines in 1960 was 16.5% while the rates for descending young gaspereau in 1960 and 1961 were found to be 52.9% and 50.3% respectively (Smith 1960;1961).

Smith (1962) indicated that the Tusket River had a fairly good-sized salmon population prior to the dam construction but that very few salmon spawners were successfully passing the hydro-electric dam. These studies conducted at the Tusket River dams in the early 1960s did not indicate any knowledge of the Atlantic Whitefish or its migrations.

A series of fish ladders was built over the years to permit fish passage around the Tusket River dams, although many were probably ineffective for Atlantic Whitefish migrations. Smith (1960;1961) indicated that the fish ladder at the Tusket River hydro-electric dam in the early 1960s was effective for gaspereau and that only a small percentage of gaspereau likely descended through the turbines. However, the fish ladder was considered very inadequate for spawning Atlantic Salmon passage and it was suggested as the major cause for reduction in the salmon production of the Tusket River (Smith 1962). Its entrance was difficult for salmon to find, and even when they did find it, they would rarely enter because of the relatively small outflow of water. While it is not known how effective the fish ladders were for Atlantic Whitefish, those that were effective exposed the whitefish to poachers. During the early 1950s, large numbers of Atlantic Whitefish were taken by poachers from the upper pools of the fish ladder constructed at the hydro-electric dam and, at least once, were loaded into a dump truck to be used as fertilizer (Scott and Scott 1988). A new fish ladder was placed at the Tusket River holding dam in 1997. It is believed to be effective, although water flows are not adequately maintained during Atlantic Whitefish migration periods (Patrick Patten, personal communication, March, 2000).

The Atlantic Whitefish population in the Tusket River watershed appears to have declined most rapidly during the 1940s and 1950s. Gilhen (1977) suggested that the abundance of Atlantic Whitefish in the Tusket River started to drop noticeably in the 1940s due to the installation of more turbines in the Tusket River hydro-electric dam, the lack of screens to prevent fish entry into dam sluices, and some ineffective fish ladders. Scott and Scott (1988) suggested that after extensive fish ladder poaching in the early 1950s, the Tusket River population never recovered to former levels of abundance.

It is probable that acidification has also contributed to the decline of the Atlantic Whitefish population in the Tusket River. While the tolerance of Atlantic Whitefish to acidification is not known, the impacts were likely comparable to impacts on Atlantic Salmon in this same river. Farmer et al. (1980) suggested that Atlantic Salmon reproduction in rivers like the Tusket could have been adversely affected by acidity by the early 1950s. Watt et al. (1983) indicate that records of angling success for Atlantic Salmon in the Tusket River suggest no trend until

the late 1940s and then declines in the 1950s. Watt (1986) suggested the decline in adult salmon returns during the 1950s in rivers like the Tusket was due to a large increase in acidic deposition during the 1945–1955 decade sufficient to overwhelm natural acid neutralization and buffering capacity in these rivers. Nova Scotian rivers with lesser declines in pH, like the Annis River and Petite Rivière, did not show an impact of acidification on angling returns (Watt 1986).

By the 1970s, it was a novelty for one Atlantic Whitefish to be captured in a single season by a gaspereau fisherman on the Tusket River (Gilhen, 1977). When Gilhen questioned gaspereau fishermen in 1977 about when they had last seen an Atlantic Whitefish, the answers ranged from 1 to 15 years. A field survey in the fall of 1982 failed to find any Atlantic Whitefish in the Tusket River despite the operation of a Department of Fisheries and Oceans fish trap on the fish ladder at the Tusket River hydro-electric dam from 5th October to 20th November (Edge 1984). This fish ladder would have been the only means for Atlantic Whitefish to migrate into fresh water since the other fish ladder at the Tusket River holding dam was not functioning because of insufficient water flow. Many gaspereau fisherman indicated in the fall of 1982 that the Atlantic Whitefish had probably disappeared from the Tusket River. However, an Atlantic Whitefish was reported to have been caught by a gaspereau fisherman in April 1996 just below the Tusket River holding dam (Patrick Patten, personal communication, March 2000). We are not aware of any reports of Atlantic Whitefish around the Tusket River dam since that time.

(2) *Annis River*

Atlantic Whitefish are reported to have been abundant in the Annis River which is a tributary flowing into the Tusket River estuary. A gaspereau fisherman on the Annis River indicated that, years ago, it was common to accidentally catch 50 to 100 Atlantic Whitefish each year in gaspereau nets (Gilhen 1977). By the early 1980s, fishermen on the Annis River indicated that catches were declining and that they had been getting a combined catch of fewer than ten whitefish each year for roughly the last ten years.

A field survey in October 1982 caught two Atlantic Whitefish in the lower Annis River (Edge, 1984). One specimen was caught on 12th October in a gillnet set in brackish water at the Annis River mouth. The other Atlantic Whitefish specimen was caught, while moving upstream on 11th October, in a hoopnet located in fresh water just above the head of high tide on the Annis River. This hoopnet operated for about 210 hours from 4 to 19 October and the Atlantic Whitefish specimen comprised about 4% of all fishes caught. A small trapnet which operated for

216 hours during the same period in brackish water at the Annis River mouth caught eels (*Anguilla rostrata*) and tomcod (*Microgadus tomcod*) but failed to catch any Atlantic Whitefish.

The Atlantic Whitefish appears to have declined significantly in the Annis River over the last 15 years. A fisherman indicated that a small population of Atlantic Whitefish was surviving in the Annis River in the early 1980s, and that he had caught several specimens in a gaspereau net at the river mouth in the spring of 1983 (Limon Earle, Pleasant Lake, 1983, personal communication). However, this fisherman indicated in September 1995, that he had not caught any Atlantic Whitefish in the Annis River in the last four or five years, and believed that the Atlantic Whitefish had probably disappeared from the river. He suggested that the recent spread of Chain Pickerel, *Esox niger*, into the lower reaches of the Annis River probably had a significant impact on Atlantic Whitefish. At present, it appears that the Atlantic Whitefish population levels have declined in the Annis River since the last COSEWIC report, although it is possible that a remnant population still exists.

(3) Petite Rivière Watershed

Little is known about the population size and trends of the Atlantic Whitefish in the Petite Rivière watershed. A small recreational fishery for Atlantic Whitefish has existed around Milipsigate and Hebb lakes since at least the 1870s (J. March, in litt., 1983). Although anglers have not considered the Atlantic Whitefish to be plentiful in these lakes, these fish were known to concentrate in schools below the Milipsigate Lake dam outlet in the spring. On these occasions, anglers could fill their creel in a short time. One angler and his son caught 24 Atlantic Whitefish at this location on 9 May 1925 (S. March, in litt., 1925). While historical knowledge of population trends in the Petite Rivière lakes is scant, Mr. J. March indicated there were persistent rumours in the early 1920s that persons dynamited schools of Atlantic Whitefish and gathered them up in nets. This type of activity could have had an influence on population sizes.

In the fall of 1982, a field survey found Atlantic Whitefish surviving in Hebb, Milipsigate, and Minamkeak lakes within the Petite Rivière watershed (Edge 1984). This survey suggested populations of Atlantic Whitefish were small based upon average catches of 0.75, 1.25, and 2.0 whitefish per 75 m gillnet set for 18 hours in Milipsigate, Minamkeak, and Hebb lakes respectively. Subsequent field studies focused on Hebb Lake in the summer of 1983, and minnow traps, seines, trapnets and gillnets were used to study fish populations (Edge 1987). Fishing methods other than gillnets indicated Banded Killifish (*Fundulus diaphanus*), Golden Shiners (*Notemigonus crysoleucas*), Ninespine Sticklebacks

(*Pungitius pungitius*) and young Yellow Perch (*Perca flavescens*) were common in shallow waters. While these methods also caught eels (*Anguilla rostrata*), Brown Bullheads (*Ameiurus nebulosus*), White Perch (*Morone americana*) and White Suckers (*Catostomus commersoni*), they did not catch any Atlantic Whitefish. Atlantic Whitefish were caught only in gillnets.

The results of gillnetting efforts in the Petite Rivière lakes in 1982 and 1983 are shown in Table 3. This table also shows Lake Whitefish gillnet capture data from other lakes in Nova Scotia for comparison. The gillnets used in 1982–1983 were 75 m in length with 15 m panels of stretched mesh sizes of 25, 37.5, 50, 75 and 100 mm that were set overnight in lakes. The gillnet data indicate the Petite Rivière lakes appear to have a predominance of White Perch, White Sucker and Yellow Perch, while Atlantic Whitefish were much less abundant. The results indicate that the 37 specimens of Atlantic Whitefish caught in 1982 and 1983 accounted for only 4.9% of all fish specimens caught in Minamkeak, Milipsigate and Hebb lakes. When considering combined fishing effort from bottom and surface set gillnets, Atlantic Whitefish appeared more abundant in Hebb Lake (0.14 specimens caught per hour of gillnet) than Minamkeak Lake (0.07 specimens), or Milipsigate Lake (0.06 specimens). The data in Table 3 also suggest Atlantic Whitefish populations in the Petite Rivière lakes are likely smaller than Lake Whitefish populations in larger bodies of water like the Mira River, Cape Breton County and Lake George, Yarmouth County Lake Whitefish were caught at a rate of 0.53 and 0.30 whitefish per hour of gillnet set in the Mira River and Lake George, respectively.

Available information would suggest the populations of Atlantic Whitefish in Minamkeak, Milipsigate, and Hebb lakes are small. A small school of Atlantic Whitefish still concentrates at the Milipsigate Lake dam outlet every spring. A visit to this location did not find any Atlantic Whitefish between 9–15 May 1983, when water temperature was 14° C. However, a small gillnet set overnight on 17 February 1985, caught five whitefish specimens at the site. Members of the Atlantic Whitefish Conservation and Recovery Team observed whitefish around the Milipsigate Lake outlet in the spring of 1999 (about 25–30 fish). In the spring of 2000 there were an estimated 200–250 Atlantic Whitefish at this dam outlet. An Atlantic Whitefish was also reported to have been caught by an angler in Fancy Lake around 1997–1998.

Little is known about the population size or trends of Atlantic Whitefish in the lower reaches of the Petite Rivière. Captain D. R. Bell, Petite Rivière, Lunenburg County has provided helpful insights on the history of Atlantic Whitefish that suggest population levels may have declined over the last few

TABLE 3. Gillnet capture data from lakes found to contain Atlantic Whitefish or Lake Whitefish in Nova Scotia. Species values expressed as number of specimens caught and per cent of all specimens caught at each location in 1982-83.

Location	gillnet effort (hrs)	Species										
		<i>Coregonus huntsmani</i>	<i>Coregonus clupeaformis</i>	<i>Salmo salar</i>	<i>Osmerus mordax</i>	<i>Alosa sp.</i>	<i>Catostomus commersoni</i>	<i>Ameiurus nebulosus</i>	<i>Morone americana</i>	<i>Perca flavescens</i>	<i>Anguilla rostrata</i>	
Atlantic Whitefish												
Minamkeak Lake	N	5	0	0	0	0	26	4	20	15	0	
	%	7					36.6	5.6	29.6	21.1		
Milipisgate Lake	N	180	11	0	0	0	0	86	10	329	43	
	%	2.3					18	2.1	68.7	9	<0.1	
Hebb Lake	N	154	21	0	0	0	0	42	2	127	8	
	%	10.8					21.5	1	62.6	4.1		
Fancy Lake	N	72	0	0	1	0	0	15	1	52	32	
	%			1			14.9	1	51.5	31.7	0	
Total	N	37	0	0	0	0	154	16	476	66	2	
(less Fancy Lake)	%	4.9					20.5	2.1	63.4	8.8	<0.1	
Lake Whitefish												
Lake George	N	0	22	0	0	0	0	0	153	25	1	
	%		10.9						76.1	12.4	<0.1	
Caribou Lake	N	28	0	1	0	0	0	9	0	9	6	
	%		4				36		36	24	0	
Lake Mushamush	N	0	2	0	0	0	36	3	39	1	0	
	%		2.5				44.4	3.7	48.1	1.2		
Mira River	N	0	25	1	1	66	8	0	23	0	0	
	%		20.2	<0.1	<0.1	53.2	6.5		18.5			
Total	N	0	50	1	1	66	53	3	224	32	1	
	%		11.6	<0.1	<0.1	15.3	12.3	<0.1	52	7.4	<0.1	

decades. Captain Bell indicated that Atlantic Whitefish have occurred in the Petite Rivière estuary since at least the 1930s and that they were caught in drift nets in the harbour for use as lobster bait. Thirty to fifty Atlantic Whitefish could be caught in ten nets over one night's fishing. Prior to the late 1940s, it was relatively common to catch them in the gaspereau fishery from mid-April to June. Only one gaspereau fisherman is now left on the Petite Rivière and he catches and releases only about two or three Atlantic Whitefish on average over an entire season. He caught and released three Atlantic Whitefish in the spring of 1999. A Department of Fisheries and Oceans trap net placed in the Petite Rivière estuary in the fall of 1999 did not capture any Atlantic Whitefish. While the numbers of Atlantic Whitefish appear to have declined since the 1930s, Captain Bell indicated it is still not uncommon at times to see Atlantic Whitefish jumping, much like a salmon on a rising tide, in the Petite Rivière estuary. It is not certain whether this is a resident population or these are strays from the Petite Rivière lakes.

Limiting Factors and Threats

(1) The Tusket River Watershed

If Atlantic Whitefish are still surviving in the Tusket River watershed, they are likely to be limited by a number of factors. Atlantic Whitefish migrations in the Tusket River may be limited by the Tusket River dams and ineffective fish ladders. Inadequate fish ladders for fish to pass around the Tusket River hydro-electric dam have been a problem for species like Atlantic Salmon since at least the 1960s (Smith 1962). While the fish ladder at the hydro-electric dam on the Tusket River that was constructed in 1979 has been used by salmon and gaspereau, it is unknown whether it is effective for Atlantic Whitefish. During the migration period of the Atlantic Whitefish in October 1982, there was little attraction water coming down this fish ladder which may have limited Atlantic Whitefish from finding the ladder. The only other fish ladder on the Tusket River at that time was at the holding dam and waterflow was so small that no fish passage was possible. While an effective new fish ladder was constructed at the holding dam in 1997, inadequate water flows during Atlantic Whitefish migratory periods likely do not permit any passage.

Water flows in the Tusket River can fluctuate widely depending upon hydro-electric power demands. At times the river can become almost dry below the holding dam potentially adversely impacting fish spawning and nursery habitats. It is unknown how these fluctuations in water flows, including those down fish ladders have affected Atlantic Whitefish movements or habitats.

Atlantic Whitefish in the Annis River are increasingly threatened by the spread of at least two intro-

duced fish species which may pose competitive or predation risks. One specimen of Brown Trout, *Salmo trutta*, was caught migrating upstream in a hoopnet on 9 October 1982, three days before the capture of an Atlantic Whitefish specimen in this same net. The Brown Trout was a female (580 mm TL) in spawning condition. Gilhen (1974) indicated Brown Trout were introduced into the Annis River around the 1920s or 1930s.

Five Chain Pickerel, *Esox niger*, were caught in October 1982, in Salmon Lake, Yarmouth County, the first major lake upstream from the Annis River mouth. Chain Pickerel were also caught in this lake by a provincial fish survey in 1977. Since the late 1980s, however, the Chain Pickerel has spread downstream to the lower reaches of the Annis River. Fishermen have recently been catching Chain Pickerel at least as large as 55 cm in the lower reaches of the Annis River where they never occurred previously (L. Earl, 1995, personal communication). These Chain Pickerel have apparently spread downstream from Salmon Lake, and they now occur throughout the lower reaches of the Annis River where Atlantic Whitefish enter fresh water. Chain Pickerel were introduced into this area many years ago and could pose a threat to salmonids (Gilhen 1974; Alexander et al. 1986; Coffie 1998).

Another limiting factor for Atlantic Whitefish in the Tusket River watershed is acidification. Many rivers in southwestern Nova Scotia have become increasingly acidified to the point where Atlantic Salmon can no longer reproduce and their native salmon populations are considered extinct (Watt et al. 1983; Watt 1986; Watt 1989). Watt (1986) indicated that a large area of Nova Scotia has already been rendered barren of Atlantic Salmon, and more is expected to be lost over the next 20 years. Watt (1986) categorized the Tusket River as a river where only remnant populations of Atlantic Salmon survive in one or two higher pH tributaries and where angling catch has declined to about 10% of levels prevalent during the 1936–1950 period. While the Annis River appears better buffered from threats of acidification, the pH in this river can drop quite low at times. Watt (1986) categorized the Annis River as a river with salmon stocks depleted by acidification of some of the smaller tributaries, but in the main stem and most tributaries, salmon production rates are normal. The tolerance of Atlantic Whitefish to acidification is unknown and it remains uncertain whether the species could continue to successfully reproduce in acidified waters like the Tusket River.

(2) Petite Rivière Watershed

The Atlantic Whitefish populations in the Petite Rivière watershed also face significant limiting factors. The Petite Rivière occurs in an area of Nova Scotia which is better buffered from the impacts of

acidification. However, the time of annual water pH minimum in the Petite Rivière lakes may coincide with the presence of acid-sensitive life history stages of the Atlantic Whitefish. In southwestern Nova Scotia, annual pH minimums typically occur from midwinter to early spring, presumably when Atlantic Whitefish eggs and newly hatched larvae would be present. The pH of Hebb Lake in February 1985 was 4.5 while the pH of the Annis and Tusket rivers in March 1985 was 5.15 and 4.66 respectively. While the failure to find young Atlantic Whitefish during surveys of the Petite Rivière Lakes in the 1980s was probably the result of inappropriate fishing methods and habitat sampling, it could also have indicated recruitment failures.

While Atlantic Whitefish could be protected from acidification by liming, such efforts may not be feasible over long periods. White et al. (1984) conducted an experimental neutralization of an acidified lake and indicated that in Nova Scotia, where retention times of most lakes are very short, neutralization of acid waters will have to be carried out at frequent intervals or continuously. Similarly, other experiments in Nova Scotia indicate that the pH of salmon streams can be adjusted to satisfactory levels (pH above 5.0) by liming, but that fresh limestone must be added annually and, in some cases, twice annually making it very expensive (Watt 1986).

The Atlantic Whitefish may also be affected by water level fluctuations in the Petite Rivière lakes and introductions of non-indigenous fish predators. While Brook Trout (*Salvelinus fontinalis*) are native to Nova Scotia, they have also been stocked into many watersheds in Nova Scotia, including the Petite Rivière. While the authors are not aware of such hatchery introductions in Minamkeak, Milipsigate or Hebb Lakes, other lakes such as Fancy, Wallace and Andrew have been regularly stocked with Brook Trout. Spread of hatchery Brook Trout could represent a threat to populations of Atlantic Whitefish and their regular introduction to Fancy Lake could contribute to the apparently only sporadic presence of Atlantic Whitefish in this lake. In addition, an unauthorized introduction of Smallmouth Bass (*Micropterus dolomieu*) took place in Wallace Lake within the Petite Rivière watershed around 1994 (A. Hebda, personal communication, 1999). These Smallmouth Bass have survived (it is reported there is now a regular bass fishing tournament), and appear to be spreading within the Petite Rivière watershed posing a potentially serious threat to Atlantic Whitefish.

It is likely there could be some continued threat from angling in the Petite Rivière watershed. While there appears to be little angling on Milipsigate and Hebb Lakes, there is more lakeshore development on Minamkeak Lake and anglers fish from boats on this

lake. For example, there is a white perch fishing season in Minamkeak Lake. It will be important to ascertain if inadvertent captures of Atlantic Whitefish while angling for other species poses a serious threat.

Special Significance of the Species

The Atlantic Whitefish is a uniquely Canadian species found nowhere else in the world. It was the first fish species to be designated as endangered by COSEWIC. It has also been featured on a Canadian postage stamp.

The Atlantic Whitefish may have some significance as a food and sport fish. Atlantic Whitefish from the Petite Rivière lakes have been described as an excellent table fish with flesh that is about the same colour as that of a herring when cooked (Piers 1927). Scott and Scott (1988) also described the Atlantic Whitefish as a good food fish of fine flavour. Anglers have described them as gamey fighters that, when hooked, almost always leap from the water until exhausted.

The Atlantic Whitefish is genetically very distinct from other whitefish species and appears to be somewhat unique in ecological aspects such as its tolerance of full seawater and warm waters. The Atlantic Whitefish likely offers a unique source of genetic diversity among salmonid species. Further study of this species will be important for understanding the biology, behavior, ecology, evolution and zoogeography of the commercially important coregonids. The extinction of the Atlantic Whitefish would be a significant loss of biological diversity.

Evaluation

Existing Legal Protection and Other Status

The Nova Scotia Fishery Regulations under section 34 of the Fisheries Act were amended 17 February 1970, to prohibit the taking of Atlantic Whitefish from all waters of the province by any method at any time of the year. A Variance Order under these Regulations was issued in 2000, that closes the area below Milipsigate Lake to any fishing from 1 April to 30 May for ten years.

The Atlantic Whitefish was classified as an endangered species by the Committee on the Status of Endangered Wildlife in Canada in 1983. It is identified on the 2000 International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species with a designation of VU D2 (Hilton-Taylor 2000). This designation implies the species is not endangered but is facing a high risk of extinction in the wild in the medium term future. The designation indicates the population is very small and is characterized by an acute restriction in its area of occupancy. The 2000 IUCN Red List identifies the species by the previously used common name of Acadian rather than Atlantic Whitefish. The

List incorrectly describes the distribution of the Atlantic Whitefish as being the Great Lakes region, including within the United States.

Assessment of Status

Since the last assessment by COSEWIC in 1983 and the IUCN in 1996, the numbers of Atlantic Whitefish have declined significantly in the Annis River. The species faces new threats from the spread of introduced Chain Pickerel into the lower reaches of the Annis River and from the spread of introduced Smallmouth Bass in the Petite Rivière watershed. In addition, the threat of acidification in both Tuskett and Petite Rivière watersheds continues. The Atlantic Whitefish should be considered as an endangered species.

Acknowledgments

This COSEWIC report is dedicated to the memory of the late Don E. McAllister and his tremendous contributions towards the conservation of biological diversity.

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The Status of the Grey Seal, *Halichoerus grypus*, in the Northwest Atlantic*

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Northwest Atlantic Grey Seals form a single population. For management purposes a Sable Island component increasing at a rate of 12.6% per year, and a non-Sable Island component increasing at a rate of $3.4 \pm 1.5\%$ per year, have been identified. Modelling population size using information on changes in pup production and age specific reproductive rates, there were an estimated 191 800 animals in 1997. Grey Seals are found in northwestern Atlantic waters throughout the year. Largely coastal in habit, they feed on a variety of pelagic and demersal fish including several commercially important species. With the exception of hunting and possibly predation from sharks no significant sources of natural mortality have been identified. Grey Seals could have a negative impact on commercial fisheries through the consumption of fish, transmission of the nematode parasite *Pseudoterranova decipiens*, and damage to fishing gear. Global climate changes would be expected to affect Grey Seals whelping on the pack-ice in the southern Gulf of St Lawrence. Currently there is no commercial hunt for Grey Seals.

Les Phoques Gris du nord-ouest Atlantique constituent une seule et unique population. Pour des fins de gestion, une composante dite 'de l'Ile de Sable', s'accroissant à un taux de 12.6% par année, et une composante dite 'non de l'Ile de Sable', augmentant à un taux de $3.4 \pm 1.5\%$ par année ont été identifiées. La modélisation de la taille de la population à partir de l'information concernant les changements de la production de nouveau-nés et du taux de reproduction à l'âge estime à 191 800 le nombre d'animaux en 1997. Les Phoques gris occupent les eaux du nord-ouest Atlantique durant toute l'année. Principalement côtiers de par leurs habitudes, ils se nourrissent d'une variété de poissons pélagiques et démersaux dont plusieurs espèces importantes commercialement. Mis à part la chasse et possiblement la prédation par les requins, aucune source de mortalité naturelle significative n'a été identifiée. Les phoques gris pourraient avoir un impact négatif sur les pêcheries commerciales par leur consommation de poissons, la transmission du nématode parasitaire *Pseudoterranova decipiens*, et les dommages infligés aux agrès de pêche. Les changements globaux de climat sont présumés pouvoir affecter les Phoques Gris lors de la reproduction sur les glaces flottantes du sud du Golfe Saint-Laurent. Il n'existe présentement aucune chasse commerciale dirigée vers les Phoques Gris.

Key Words: Pinnipedia, Phocid, *Halichoerus grypus*, Grey Seal, Phoque Gris, Northwest Atlantic.

The Grey Seal (family Phocidae) was first described by Fabricius (1791). Its name *Halichoerus* comes from the Greek meaning "sea pig", and *grypus* from the Latin meaning hook-nosed (Bonner 1981). In Canada, they are sometimes referred to as horse-head seals owing to the elongated snout of the males (Figure 1). Males tend to be darker in colour than females, in some cases almost black. They may reach a length of 231 cm (McLaren 1993), and have a mean weight of 298 kg (SD = 29.5) during the breeding season (Tinker et al. 1995). Females are smaller, with a length of 201 cm (McLaren 1993) and a weight of 227 kg (SD = 26) (Baker et al. 1995). The pups are born with a white lanugo, which they begin to shed approximately nine days after birth, and is completely replaced by a black spotted, silver coat by the 25th day (Davies 1949; Bowen and Stobo unpublished in Renouf 1990).

Grey Seals are considered to be a coastal species. They may forage far from shore, but do not appear to leave the continental shelf regions (Gosselin and Hammill, unpublished data). They haul out on exposed reefs or on beaches of undisturbed islands. These concentrations of animals are typically quite noisy (Lesage and Hammill, personal observation), and are associated with vocalisations resembling growls and roars (Schneider 1974). These noises sometimes resemble the calling of a wolf, and this may be the source of the general French term 'lousps marins' (which means sea wolves).

Distribution

Grey Seals are found throughout the temperate North Atlantic. Three distinct populations are recognised: the Baltic Sea population, a North-Eastern Atlantic population that extends from Iceland to Norway, but with the main concentration around the United Kingdom, and a North-Western Atlantic population (Davies 1957). An examination of mitochondrial DNA variation in samples from Canada, Norway

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and the Baltic Sea supports the hypothesis that seals from these areas do represent three distinct populations. Eastern and western Atlantic Grey Seals diverged first, possibly 1.0–1.2 million years ago, while the Baltic Sea animals diverged much later (Boskovic et al. 1996).

In the Northwest Atlantic, Grey Seals have been found as far north as Cape Chidley, at the northern tip of Labrador, and as far south as Virginia in the USA (Katona et al. 1993). In Canada, the largest concentrations of animals outside of the breeding season are found around Sable Island, and in the northern Gulf of St Lawrence around Anticosti Island (Clay and Nielsen 1985; Stobo et al. 1990; Lavigne and Hammill 1993) (Figure 2). With the increase in the Grey Seal population there has been an increase in sightings along the New England, United States coast (Katona et al. 1993), along the Lower North Shore of Quebec (G. Beck, Toronto Ontario, personal communication) and in the Strait of Belle Isle (G. Stenson, DFO St John's Newfoundland, personal communication).

The Northwest Atlantic Grey Seals form a single population (Boskovic et al. 1996), but for management purposes, they are divided into two major groups based on the locations of the whelping patches. The largest group whelps on Sable Island, a 40 km long sand spit located approximately 250 km to the east of Nova Scotia (Figure 2). The second group, known as non-Sable Island Grey Seals, is largely made up of animals that whelp on drifting pack ice in Northumberland Strait and along the west coast of Cape Breton Island in the southern Gulf of St Lawrence. Smaller groups of non-Sable Island Grey Seals also whelp on small islands or reefs located in the southern Gulf of St Lawrence, and along the eastern shore of Nova Scotia (Mansfield and Beck 1977). In recent years, a new colony numbering 600+ pups has formed on Hay Island off the Cape Breton coast (Figure 2). New pupping colonies have also formed in Maine and in Massachusetts (Hannah 1998). Although Sable and non-Sable Island animals show strong philopatry to their whelping sites, some exchange of adults between breeding colonies has been documented and may be in the range of 5% (Zwanenburg and Bowen 1990). Considerable overlap occurs between the two groups outside of the breeding season (Stobo et al. 1990; Lavigne and Hammill 1993).

Movements

Information on movements of Grey Seals is available from anecdotal sightings, recovery of tags from shot animals or strandings and more recently from satellite telemetry.

Sable Island Grey Seals have a post-breeding pelagic phase (February–April) when they disperse from the island. This is followed by a spring moult (May–June), when animals return to Sable Island.

After they have completed their moult, there is a second, summer dispersal away from the island (July–September). At this time, animals may move towards the Nova Scotia, Maine, and Newfoundland coasts, and into the Gulf of St Lawrence. They return to Sable Island during the fall and early winter (October–December) (Stobo et al. 1990).

This general movement pattern is also true for non-Sable Island Grey Seals. Tag returns and satellite telemetry indicate that after breeding, the majority of adult Grey Seals move out of the Gulf of St Lawrence onto the Scotian shelf (Hammill et al. 1993; Lavigne and Hammill 1993; Goulet et al. 1995), where they remain offshore until the spring moult. The pups tend to remain with the pack ice as it drifts around the west side of the Cape Breton coast into the Atlantic. However, in some years, ice drift is slow, or there is little ice available which breaks up early in the season. When this occurs, many animals move ashore onto the beaches of Prince Edward Island, Cape Breton Island and mainland Nova Scotia, where mortality may be high. During May–June, both adults and juveniles move ashore to moult. Although some animals moult throughout the Gulf of St Lawrence, most appear to move into the northern Gulf of St Lawrence, around Anticosti Island, and along the Lower North Shore (Clay and Nielsen 1985). After the moult, animals disperse, with many animals moving into the St Lawrence Estuary (Lavigne and Hammill 1993). In late fall, Grey Seals return to the southern Gulf of St Lawrence or to Sable Island for the breeding season. This movement, which often occurs in November–December, usually takes only a few days (Goulet et al. 1995; Gosselin and Hammill 1998).

Protection

International Protection Measures

In the United States of America, all marine mammals are protected from hunting, except for subsistence hunting by aboriginal people, under the Marine Mammal Protection Act of 1972. Grey seals are completely protected from hunting in France, Denmark, Finland, Sweden and the Netherlands. In the United Kingdom and Ireland they are protected from hunting, but exemptions exist for killing seals to protect fisheries or for scientific purposes. In Iceland, Grey Seals are not protected and may still be hunted. In Norway, Grey Seals are protected in areas south of 62°N. Hunting is permitted from 1 November to 30 April between 62–67°N, and from 1 December to 30 April north of 67°N. In the Faeroe Islands, Grey Seals may only be killed using guns. Licences for guns are mainly restricted to aquaculture operations.

National Protection Measures

In Canada marine mammals fall under federal jurisdiction. Grey Seals were managed under the Seal Protection Regulations of the Fisheries Act



FIGURE 1. The Grey Seal (*Halichoerus grypus*) [photo by Mike Hammill].

since 1966. In February 1993, the Seal Protection Regulations were superseded by the Marine Mammal Regulations of the Fisheries Act. These regulations govern scientific research activities, marine mammal ecotourism and observation, and hunting activities. Licences are currently issued to non-natives to hunt Grey Seals in Canadian waters. There is also a provision for personal sealing licences, which allows the holder to take six seals

annually. The harvest, either for commercial or personal purposes, is restricted by an obligation to make full use of the entire carcass of the killed seal. Hunting is not permitted during the breeding season, *i.e.* in January and February. Furthermore, it is illegal to hunt Grey Seals during the summer (May/1 June to 30 September) to the west of $67^{\circ}23'$ (Pointe-des-Monts) in the St Lawrence Estuary and Saguenay River, in certain regions adjacent to the coast of New Brunswick, the Magdalen Islands, and Murray Harbour (Prince Edward Island), and throughout the year near the Gaspé coast. The Minister of Fisheries and Oceans can modify closure dates by the release of ordinances and variances.



FIGURE 2. Main whelping sites of land-breeding (G) and ice-breeding (dotted area) Grey Seals.

Population Sizes and Trends

Grey seals were at one time abundant and widely distributed along the Canadian east coast and in the Gulf of St Lawrence where they were first hunted by Amerindians. Hunting by Europeans, particularly after the disappearance of the Walrus (*Odobenus rosmarus*) in the Gulf and on Sable Island, resulted in the depletion of the Grey Seal population by the mid-1800s (Lavigne and Hammill 1993). By the early 1900s, Grey Seals were still considered to be widely distributed, but there was no particular hunt for them, owing to their small numbers (Comeau 1945). During the 1950s, the Grey Seal was considered to be uncommon or rare in eastern Canada. Nevertheless, Grey Seals continued to be hunted. In 1927, the Canadian government initiated a bounty program directed towards another seal species, the Harbour

Seal (*Phoca vitulina*), under which a reward was paid to fishermen upon receipt of a seal snout. In 1949, the system was changed to require presentation of the lower jaw to receive the bounty. Since it is possible to identify the species by the lower jaw, it became apparent that some Grey Seals had been collected in small numbers (Mansfield and Beck 1977). Between 1967 and 1984, the Canadian Department of Fisheries and Oceans conducted an annual cull for Grey Seals at breeding colonies in the Gulf of St Lawrence, and along the Nova Scotia eastern shore, removing 114 to 2375 animals annually (Zwanenburg and Bowen 1990). From 1978 until 1990, a bounty was paid to licensed fishermen who submitted lower jaws from Grey Seals, and information on date and location of capture. A total of 4379 individuals were taken during this program. Captures were initially quite high, but with the exception of a large number of jaws received in 1989 (753), they declined steadily until 1990, when only 79 jaws were received (Lavigne and Hammill 1993).

In spite of continued hunting, the Northwest Atlantic Grey Seal population has increased. On Sable Island, where hunting pressure has been much less intense than elsewhere, Grey Seal pup production was determined by complete enumeration between 1977 and 1990. Counts on Sable Island indicate that pup production has increased at a rate of 12.6% per year from 2200 pups in 1977 to 9700 in 1989 (Stobo and Zwanenburg 1990). Zwanenburg and Bowen (1990) modelled the dynamics of the Sable Island component of the population to estimate total population size, and to monitor changes in this component of the population since the 1960s. They modified estimates of first year survival and age-specific pregnancy rates (Mansfield and Beck 1977) and assumed that during the 1960s, the Sable Island component represented a closed stable population. Using a first year survival of 0.787, and an annual adult survival rate of 0.96 (Zwanenburg and Bowen 1990) to generate the observed rate of increase in pup production, the Sable Island Grey Seal component of the population would have increased from 2200 animals (rounded to the nearest hundred) in 1962 to about 42 000 animals in 1987 (Zwanenburg and Bowen 1990). Expanding the period covered by Zwanenburg and Bowen (1990) to 1994, and applying a different model, the Sable Island component of the population has increased to 85 300 (78 000 – 95 000 95% confidence interval) animals (Mohn and Bowen 1996). Recent surveys to determine Sable Island pup production were flown in 1997. These surveys estimated pup production to be 25 200 (23 700 – 26 700 95% confidence interval) (Bowen et al. 1999) which would result in a total population of 144 700 animals (Figure 3) (Hammill 1999).

Much less information is available concerning the

size of the non-Sable Island component of the population, owing to the difficulties of working on the unstable pack-ice in the southern Gulf of St Lawrence. Non-Sable Island pup production has been determined from mark-recapture experiments conducted between 1984 and 1990, where the pups were marked on the whelping patch, and later shot during scientific collection programs or by recapturing the animals live on Sable Island 3–10 months later (Stobo and Zwanenburg 1990; Hammill et al. 1998). Early estimates suggested that pup production during the period 1984–1986 could have been as low as 5300 ± 2600 or as high as $11\,700 \pm 3000$ animals (Stobo and Zwanenburg 1990). However, because several of the assumptions related to the Peterson mark-recapture model were violated, it was concluded that the true pup production probably lay in between these estimates (Stobo and Zwanenburg 1990). A re-analysis of these estimates and some new data from 1989 and 1990 indicated that pup production of the non-Sable Island component would have increased from an estimated 5900 pups in 1984 to 9300 in 1990 for an annual rate of increase of 7.4% (SE=2.2) (Hammill et al. 1998). More recent estimates of pup production from aerial surveys estimated a pup production of 11 800 (6800–16 900) in 1996 and 7400 (4600–10 400) in 1997 resulting in a rate of increase of 3.4% (SE=1.5) (Hammill et al. 1999). The lower estimates obtained in 1997 are attributed to high pup mortality owing to poor ice conditions encountered in that year (Hammill et al. 1999). The dynamics of this component of the population have been modelled using a model similar to the one developed by Zwanenburg and Bowen (1990). Assuming that differences in population growth between the Sable and non-Sable components of the population are due to differences in pup survival rates, then the 3.4% rate of increase is achieved using adult survival rates of 0.96 (Zwanenburg and Bowen 1990), and pup survival rates of 0.329. This results in a 1984 population of 28 400 in 1984 increasing to 47 100 in 1997 (Figure 3) (Hammill 1999). Combining the estimates for the Sable Island and non-Sable Island components results in a total Northwest Atlantic Grey Seal population of 191 800 in 1997 (Hammill 1999).

It is evident that the Sable Island and non-Sable Island components of the population must have undergone very different trajectories since the 1970s. During that decade, roughly 69% of the population was of non-Sable Island origin, consisting mostly of animals from the Gulf of St Lawrence. However, by 1993 less than 43% of the total population would have been of Gulf origin (Mohn and Bowen 1996). Differences between the two groups likely result from the effects of the government sponsored cull of non-Sable Island animals in the whelping areas, and also from higher mortality rates for pups born on the

unstable pack-ice in the Gulf of St Lawrence (Hammill et al. 1995).

Habitat

Grey Seals inhabit temperate cold waters throughout their range. Whelping occurs during late December–February (Mansfield and Beck 1977) in two very different environments: the unstable drifting pack-ice in the southern Gulf of St Lawrence, and on beaches of isolated islands (Figure 2) (Mansfield and Beck 1977). After breeding, animals move offshore onto the Scotian Shelf or over the Laurentian Channel between the Magdalen Islands, Newfoundland and Cape Breton Island, presumably to feed (Stobo et al. 1990; Hammill et al. 1993; Goulet 1996). Dives to deeper than 400 m have been recorded, but the majority of dives are to depths of 70–100 m (Goulet 1996). In May and June, they move ashore to moult on beaches of remote, and often small islands or on reefs exposed at low tide (Mansfield and Beck 1977; Clay and Nielsen 1985). They remain in these areas throughout the summer and the fall, partitioning their time between periods of hauling out, and periods at sea. Movements in the Gulf of St Lawrence appear to be largely coastal (Goulet 1996), but a different pattern may occur off Sable Island. In European waters, animals at this time of year tend to move between a restricted number of haul out sites (Thompson et al. 1991; Sjøberg et al. 1995).

General Biology

Reproduction

The mean age for females giving birth for the first time is 5.5 y (SD = 0.12). Pregnancy rates for female Grey Seals, using the presence or absence of a foetus, are 0.18, 0.86 and 0.88 for females aged 4+, 5+ and 6+ years respectively (Hammill and Gosselin 1995). Among males, a marked increase in testis weight is observed at age 3+ y. Based on testis mass, the mean age of sexual maturity is 5.6 y, and by age 7 virtually all males are sexually mature (Hammill and Gosselin 1995). However, animals do not appear to be able to hold tenure in the whelping patch until the age of 11–12 y (Godsell 1991).

Pupping occurs during late December to February. A female Grey Seal usually gives birth to a single pup after a 12-month gestation period, which includes a 3-month period of delayed implantation and a 9 month active gestation period. At birth, the pups weigh 15–17 kg, and gain 2.4–3.0 kg/d. They are weaned at a mass of 51–56 kg after a 15–16 day lactation period (Bowen et al. 1992; Iverson et al. 1993; Baker et al. 1995). Males can be heavier at birth, grow faster, and weaned at a greater mass (Baker et al. 1995), but this has not been observed in all studies (Bowen et al. 1992; Iverson et al. 1993). During lactation, females lose approximately 3–9 kg/d (Iverson et al. 1993;

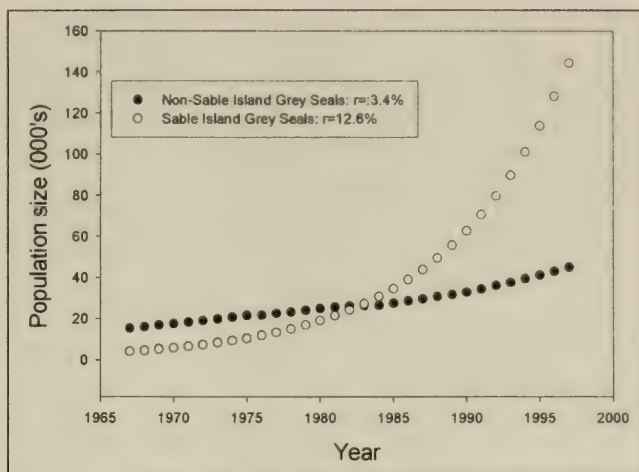


FIGURE 3. Changes in abundance of NW Atlantic Grey Seals (modified after Hammill 1999).

Lydersen et al. 1994; Baker et al. 1995). Females in land-breeding colonies fast during the lactation period (Iverson et al. 1993), but some females breeding on the pack-ice may feed (Lydersen et al. 1994; Baker et al. 1995).

Grey Seals are polygynous (Cameron 1967). Males do not defend fixed territories, but instead compete for access to a shifting population of lactating females (Boness and James 1979). The degree of polygyny is affected by habitat variability (Anderson and Harwood 1985; Bédard 1993; Tinker et al. 1995). Males attending females lose 2–5 kg/d during the breeding season (Godsell 1991; Tinker et al. 1995). Copulation occurs on land or in the water at the end of lactation (Bonner 1981).

Grey Seal mortality rates have not been measured directly. Animals as old as 46+ y have been collected from the wild (Hammill, unpubl. data). As outlined above, adult survival rates of 0.96 and pup survival rates of 0.79 were required to obtain a rate of increase in pup production of 12.6% for Sable Island. For the non-Sable Island population, the observed rate of increase in pup production was obtained with adult survival rates of 0.96 and pup survival rates of 0.33. These represent mean survival rates.

Food Habits and Feeding

Over 40 different prey species, including many commercially important species, have been identified in the diet of Northwest Atlantic Grey Seals (Benoit and Bowen 1990a). Like most pinnipeds, strong regional and seasonal changes in Grey Seal diets have been observed. In the northern Gulf of St Lawrence, Capelin (*Mallotus villosus*), Lumpfish (*Cyclopterus lumpus*), Herring (*Clupea harengus*), and Atlantic Cod (*Gadus morhua*) are the most important prey species, accounting for over 60% of the diet by frequency of occurrence (Benoit and Bowen 1990b; Murie and Lavigne 1992; Proust 1996). Seasonal changes in diet are evident, with

Capelin and Lumpfish being important prey from May to July. During August and September, Cod and Herring are the dominant prey species (Benoit and Bowen 1990b; Proust 1996). In the southern Gulf of St Lawrence, Cod, Herring and flatfish (Pleuronectiformes) are the most important prey (Benoit and Bowen 1990a). In Grey Seals collected from the Atlantic side of Nova Scotia and Sable Island, Cod, Herring, Silver Hake (*Merluccius bilinearis*), Sand Lance (*Ammodytes americanus*) and flatfish form the most important prey (Bowen et al. 1993; Bowen and Harrison 1994). Near Sable Island, Sand Lance are an important component of the diet throughout the year, but account for a greater percentage of the diet by weight during the winter than in summer. Cod and Silver Hake are consumed primarily during late summer when these species move into the shallower water over the offshore banks surrounding Sable Island (Bowen and Harrison 1994). Some differences occur between nearshore diets from the Nova Scotia Eastern Shore and offshore diets of animals from around Sable Island (Bowen and Harrison 1994). In Grey Seals collected from nearshore areas, Herring and Mackerel (*Scomber scombrus*) replace Sand Lance and flatfishes as the most important foods (Bowen et al. 1993).

Grey Seals feed primarily on fish < 40 cm in length, which for most species represent fish too small for the commercial fishery (Benoit and Bowen 1990b; Murie and Lavigne 1992; Bowen et al. 1993; Bowen and Harrison 1994; Proust 1996). Some notable differences have been observed between studies or within studies between years. Bowen et al. (1994) observed that Grey Seals consumed larger Herring during the fall on the Scotian Shelf (mean length = 34.5 cm) than did Grey Seals feeding on Herring during summer in the northern Gulf (mean length = 24.9 cm) (Benoit and Bowen 1990b). More recently, Proust (1996) observed that Grey Seals ate smaller Cod in 1988 (mean length = 32.1 cm) than in 1992 (mean length = 39.6 cm). These differences in the length-frequency distributions of prey consumed may be related to the relative abundance of particular year classes (Proust 1996).

Behaviour and Adaptability

While at sea, Grey Seals appear to travel singly. Haul-out sites and whelping areas are normally located in remote areas where access is limited (Mansfield and Beck 1977; Clay and Nielsen 1985; Lesage et al. 1995). Grey Seals react to approaching boats or low flying aircraft, even when these sources of disturbance may still be a considerable distance away, by entering the water and dispersing from the site (Lesage and Hammill, personal observation), but this may vary between regions. For example, on Sable Island Grey Seals appear to be tolerant to disturbance and do not enter the water until approached closely (Lesage and Hammill, personal observation).

Limiting Factors

Past exploitation greatly reduced Grey Seal numbers in eastern Canada (Lavigne and Hammill 1993). In spite of government cull programs and bounty programs, Grey Seals numbers appear to have been increasing since the early 1960s (Zwanenburg and Bowen 1990). Catch statistics (Department of Fisheries and Oceans, Ottawa) indicate that current levels of hunting remove less than 500 animals per year from the population. Grey Seals can be sensitive to human disturbance. During the breeding season, this can result in the abandonment of the pup by the female and consequent pup mortality (Lesage and Hammill, personal observation).

Quality of the whelping habitat can have an important impact on the species. On small islands that are repeatedly disturbed, Grey Seals may abandon these sites (e.g., Basques Island). For Grey Seals whelping on the shifting pack-ice, thin or otherwise poor ice will lead to high pup mortality, which will result in very limited or no increase in population size in some years. Climatic changes resulting in changes in ice cover in the Gulf of St Lawrence will affect the availability of whelping habitat. A decline in ice cover will force animals to whelp onshore in the southern Gulf of St Lawrence where they will be exposed to disturbance or hunting by humans. This could lead to a reduction in whelping activity in the Gulf of St Lawrence.

Grey Seals are subject to predation by sharks. Little information is available, but it has been proposed that one factor contributing to the rapid increase in Grey Seal numbers on Sable Island has been an apparent decline in shark abundance (Brodie and Beck 1983).

It has been hypothesised that the northern limits of Grey Seals are limited by the effects of cold temperatures on the thermoregulatory abilities of pups during their post-weaning fast (Hansen and Lavigne 1997). Hansen and Lavigne (1997) found that the lower critical temperature of pups during the post-weaning fast was -7.1°C . The current distribution of the -7.5°C January-February mean air temperature isotherm would exclude breeding Grey Seals from the western portion of Northumberland Strait, and much of the Gulf of St Lawrence lying to the west and north-west of a line extending from Cape North (northwestern Prince Edward Island) to the Bay of Islands on the west coast of Newfoundland (Hansen and Lavigne 1997).

High contaminant burdens could have a negative impact on Grey Seals. A reduction in reproductive rates due to uterine stenosis and uterine occlusions has been associated with PCB levels of 73 ± 6.6 to 100 ± 13 mg kg^{-1} wet weight in blubber from Baltic Sea Grey Seals (Helle et al. 1976; Bergman and Olsson 1985). However, published information on contami-

nants in Northwest Atlantic Grey Seals indicates that organochlorine levels are much lower, and some are declining (Addison et al. 1984). A decline is occurring rapidly in DDT-group insecticides, while PCB residues show little evidence of change, or may have increased. In a sample from lactating females collected on Sable Island, DDT concentrations declined markedly from 12.7 ± 6.2 mg kg⁻¹ in 1976 to 3.7 ± 1.4 mg kg⁻¹ in 1985, while PCB concentrations changed little (11.7 ± 4.4 in 1976 compared to 16.2 ± 6.8 mg kg⁻¹ in 1984, and 30.3 ± 17.0 mg kg⁻¹ in 1985) (Addison et al. 1984; Addison and Brodie 1987). In a more recent sample from Sable Island, total DDT levels were 1.4 ± 0.4 mg kg⁻¹ and 2.5 ± 1.5 mg kg⁻¹ in weaned pups and yearlings, respectively. PCB levels were 2.4 ± 1.3 mg kg⁻¹ and 4.1 ± 2.1 mg kg⁻¹ in pups and yearlings, respectively (Addison and Stobo 1993). No information is available for Grey Seals from the Gulf of St Lawrence, but in the St Lawrence Estuary area, levels of PCB in immature grey seals were 4.212 ± 1.580 mg kg⁻¹ (n=14) and in adults 9.978 ± 5.555 mg kg⁻¹ (n=5). Levels of DDT were 2.030 – 1.280 mg kg⁻¹ (n=14) in immature and 2.379 ± 1.247 mg/kg (N=5) in adult Grey Seals (Bernt et al. 1999).

In 1988, a morbillivirus, phocine distemper virus (PDV), killed more than 18 000 Harbour Seals, and a small number of Grey Seals in northern Europe (Heide-Jørgensen et al. 1992). Morbillivirus neutralising antibodies have been identified in Grey Seals from the Northwest Atlantic, with the highest titers against phocine distemper virus (Duigan et al. 1995). It has been proposed that a PDV-like morbillivirus is enzootic in Grey Seals, and that the virus constantly circulates within the population. Although some mortality would occur, the overall effect would be to maintain a certain level of herd immunity, which would limit the potential for an epizootic outbreak (Duigan et al. 1995).

Special Significance of the Species

Grey Seals are found in north-western Atlantic waters throughout the year. There are conflicts with commercial fishermen owing to consumption of commercially important species of fish, damage to fishing gear, and through their role as a terminal host for the nematode parasite *Pseudoterranova decipiens* (Bowen 1990).

Atlantic groundfish stocks collapsed during the early 1990s, and have shown little sign of recovery. Grey Seals may consume significant quantities of commercially important species, but the impact of Grey Seals on fish stocks cannot be assessed until mortality rates due to seal predation can be placed within the context of total natural mortality experienced by the fish (Mohn and Bowen 1994; Hammill et al. 1995).

Damage to fishing gear in the Atlantic region was examined by the Royal Commission on Seals and

Sealing (Malouf 1986). Based on a series of questionnaires and/or personal interviews conducted in Nova Scotia, it was concluded that damage to fishing gear by both Harbour Seals and Grey Seals in 1983 could have been as much as \$1 241 000. Assuming that damage to gear in New Brunswick and Prince Edward Island was approximately one third of the Nova Scotia value for each province, the total value would have been \$2 068 333.

Four species of pinnipeds are abundant throughout Atlantic Canada, but the Grey Seal is the most important as a vector for the nematode parasite *Pseudoterranova decipiens*, known also as codworm or sealworm (Mansfield and Beck 1977; Bowen 1990). Sealworm is considered to be mildly pathogenic in humans if consumed in raw or poorly cooked fish. However, their major impact on fisheries is considered to be a cosmetic one, with high infections rendering fish unappealing to consumers. The cost of removing larvae from cod fillets alone was estimated to be in excess of \$29 million in Atlantic Canada in 1982 (Bowen 1990). Surveys conducted during the 1980s and in 1990 indicate that worm burdens in fish have increased in both the Gulf of St Lawrence and on the Scotian Shelf (McClelland et al. 1985; Boily and Marcogliese 1995). These increases may be linked to an increasing Grey Seal population (Marcogliese et al. 1996).

Owing to its scarcity during the 1800s and in the present century, Grey Seals have not been hunted commercially. However, with the recent expansion of the Grey Seal population, there is some interest in hunting these animals. Grey Seals offer limited potential for ecotourism in the breeding colonies because of their large size and the aggressive nature of both adults and pups.

The Grey Seal shows perhaps the greatest variability of all pinnipeds in the selection of whelping habitat. Habitat types vary from sandy beaches, caves accessible only from the sea, to rocky islands and pack-ice. The occurrence of Grey Seals breeding on the pack-ice in the southern Gulf of St Lawrence is very unusual and occurs in only one other place in the world, the Baltic Sea.

Evaluation

Grey Seals appear to be susceptible to disturbance at whelping and haul-out sites. Consequently, they tend to be more abundant in sparsely inhabited areas. Presently, there is no commercial hunt for this species, although this could change in the near future.

The Northwest Atlantic Grey Seal population is probably more abundant now than at any previous time in the present century. Information on trends in pup production (an index of population size) indicate that the population is continuing to expand. Grey Seal populations whelping on the pack-ice in the southern Gulf of St Lawrence and on Sable Island are both abundant, but a series of winters with poor

ice conditions will have a negative impact on the Gulf component of the Northwest Atlantic Grey Seal population, possibly leading to no or negative growth. It is recommended that, for the present time, the species should not be given any COSEWIC category, but the Gulf component should be monitored for any change in abundance.

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Status of Harbour Seals, *Phoca vitulina*, in Canada*

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The Harbour Seal (*Phoca vitulina*) inhabits all three of Canada's coastlines, as well as a number of fresh-water systems. Three subspecies are recognized from Canadian waters, *Phoca vitulina richardsi* from the Pacific coast, *Phoca vitulina concolor* from the Atlantic and Arctic coasts, and *Phoca vitulina mellonae* from several freshwater lakes on the Ungava Peninsula, Quebec. This report reviews the status and management of *Phoca vitulina richardsi* and *Phoca vitulina concolor* in Canadian waters, discussing distribution, movements, population discrimination, population size and trends, and threats to this species in Canada. The Harbour Seal population in western Canada is large and has been increasing in size. While there are a number of actual or potential anthropogenic threats, including: overfishing, immunosuppression due to accumulation of toxins, and illegal killing associated with aquaculture operations, the western Canadian population should probably be listed as not at risk. Little recent research has been undertaken on Harbour Seals in the Canadian Arctic or for most areas off eastern Canada, and insufficient information is available to assess the status of these populations.

Key Words: Harbour Seal, Phoque Commun, Loups Marin, Kasigiak, *Phoca vitulina richardsi*, *Phoca vitulina concolor*, Pacific, Atlantic, Arctic, Phocid, status, pinniped.

The Harbour Seal (*Phoca vitulina* Linnaeus, 1758, Figure 1), known in Quebec as Phoque Commun or Loups Marin, in parts of northern Canada as the Ranger Seal or Kasigiak, and in Europe as the Common Seal, is a small coastal Phocid, and is one of the most widely distributed pinnipeds in the northern hemisphere. On both the east and west coasts of Canada Harbour Seals average about 80 cm at birth (McLaren 1993). The average adult length is about 1.5 m, and they have been recorded to reach a maximum length of about 1.9 m (Boulva 1971; Bigg 1981; McLaren 1993). Males are usually slightly larger than females (5% off Nova Scotia, 13% off British Columbia; McLaren 1993). Harbour Seals have been described as "large-headed, short-bodied and short-limbed" (Figures 1 and 2), and have an extremely variable pelage pattern with spots, rings and blotches which range in color from light grey to dark brown or black on either a light or dark background (Stutz 1967; Bigg 1981). Harbour Seals usually lose their lanugo (white) coat in utero, though Boulva (1971) and Oftedal et al. (1991) noted 16% and 6% (respectively) of the pups born at Sable Island have a lanugo coat. Individuals with rust-coloured coats, particularly on the head and upper body, have also been observed (Jefferson et al. 1993). The eyes are large and set close together, and the nostrils form a distinct "V" shape. Harbour Seals are usually very

difficult to approach on shore. They are gregarious on land, but usually solitary or in very small groups when seen in the water. Most of time Harbour Seals spend on shore they just lay on the substrate with periodic checks of their surroundings, but often also lie with their head and hind flippers elevated in a characteristic crescent position (Katona et al. 1993; Figure 2).

Considerable taxonomic uncertainty has existed regarding Harbour Seals, both at the sub-specific and specific levels (e.g., McLaren 1966; Shaughnessy and Fay 1977; Bigg 1981; Smith et al. 1994; O'Corry-Crowe and Westlake 1997). Until recently, Harbour Seals and Largha Seals (*Phoca largha*) were frequently lumped as one species, *Phoca vitulina*, resulting in some confusion as to, for example, geographic range (O'Corry-Crowe and Westlake 1997). Three subspecies of the Harbour Seal are currently recognized from Canadian waters, with *Phoca vitulina richardsi* in the Pacific, *Phoca vitulina concolor* in the Atlantic and Arctic, and *Phoca vitulina mellonae*, the Lacs des Loups Marins Harbour Seal, found exclusively in freshwater lakes in Quebec's Ungava Peninsula (Smith et al. 1994). The status of this latter population has been recently reviewed (Smith 1997) and classified by COSEWIC (the Committee on the Status of Endangered Wildlife in Canada) as "Vulnerable".

The purpose of this report is to review available information and assess the status of the other two subspecies of Harbour Seal found in Canadian waters, on behalf of COSEWIC. While they are one of the most well-studied pinnipeds (Cottrell 1995), surprisingly little recent information is available regarding population size, trends, and sources and

*Reviewed and approved by COSEWIC, April 1999, status assigned — Atlantic and Arctic coastal waters Indeterminate, North Pacific coastal waters Not At Risk.



FIGURE 1. Harbour Seal hauled out on rocky substrate off southern Vancouver Island. Photo by the author.

levels of anthropogenic mortality in Canadian waters.

Distribution

Harbour Seals have a coastal distribution in temperate, sub-Arctic and some Arctic waters throughout the northern hemisphere, with some populations also occurring in fresh-water systems. In the Pacific, they are found from northern Japan (Hokkaido), through the Aleutians and the Gulf of Alaska, and south along the coast of North America as far as western central Baja California, Mexico. Records reported from Alaskan waters of the Beaufort Sea (e.g., Mansfield 1967) are of Larga Seals. In the Atlantic, Harbour Seals have been documented as far south as Florida (Reeves et al. 1992), and occur regularly from New York and New England north to Greenland, Iceland, the UK, Norway and Svalbard (Wiig 1989), and south as far as Brittany, France.

In Canada, Harbour Seals are found in coastal waters in the Pacific and Atlantic oceans, as well as in parts of Hudson Strait, Ungava Bay, Hudson Bay and around Baffin Island (Figure 3; Mansfield 1967; Beck et al. 1970; Bigg 1981). While sightings in Canadian waters have been reported as far north as Ellesmere Island (79°N), no recent information is available on their distribution in the Canadian Arctic, and there is some evidence to suggest that their distribution in the Arctic may have changed. Mansfield (1967) noted that Harbour Seals had been eliminated from some areas in the Canadian Arctic by native hunting.

As mentioned above, Harbour Seals can also be found in fresh water, including not only the population which resides year-round in the Seal Lakes (Lacs des Loups Marin) in northern Quebec, but also

rivers and lakes on other coastlines. In western and northwestern Hudson Bay Harbour Seals have been recorded as far as 240 km inland in several rivers and lakes (Mansfield 1967; Beck et al. 1970), and on the Pacific coast, Harbour Seals also enter small rivers and lakes, occasionally as far as 300 km inland (Fisher 1952). In eastern Canada, Harbour Seals were once found in a number of fresh water systems, including Lake Champlain and Lake Ontario (Allen 1880). It appears their use of fresh water systems in eastern Canada has declined; Boulva and McLaren (1979) noted that Harbour Seals seldom reach Montreal in the St. Lawrence River. Similarly, Lesage et al. (1995b) report relatively few in the Saguenay River in 1994, while Boulva and McLaren (1979) reported a population of approximately 100 individuals in that river in 1973 (it should be noted however that the methods of these two studies differ greatly, and numbers in each are not comparable).

Movements and Population Discrimination

On land, Harbour Seals exhibit fairly poor mobility, with movements typically restricted to tens of meters. However, Renouf and James (1975) state that pregnant females have been known to travel more than a kilometer overland on Sable Island, to give birth on the shores of inland lakes.

Harbour Seals are generally considered to be non-migratory (Bigg 1981), being present in most areas year-round, and showing considerable site fidelity (e.g., Olesiuk et al. 1995). However, extensive movements do occur. Based on seasonal decreases in counts at haul-outs in the Bay of Fundy, and corresponding increases in numbers hauled out in Maine, Rosenfeld et al. (1988) suggested that there is a seasonal movement of Harbour Seals between these two



FIGURE 2. Harbour Seals hauled out on dock, Victoria Harbour. Note the individual on the left is lying with head and tail raised, a typical posture for Harbour Seals. Photo by the author.

areas. Using satellite tags on individuals in the St. Lawrence estuary, Lesage et al. (1995a) documented a migration of one individual which moved 520 km to overwinter, and returned to the same summering area the next year. In terms of dispersal from breeding areas, Beck (1983) noted that juveniles tagged at Sable Island, off Nova Scotia, moved to various mainland sites, and included one individual which moved to New Jersey, a straight line distance of 1475 km.

Despite such long-ranging movements, there is a variety of evidence that suggest Harbour Seals on the west coast of Canada may be subdivided into two or more populations (Stutz 1967; Temte et al. 1991; Burg 1996; Lamont et al. 1996). Stutz (1967) noted geographic variation in pigmentation patterns for several areas on the coast of British Columbia and southeast Alaska and suggested these reflect subdivision of the population. Yochem et al. (1990) documented geographic variation in pigmentation patterns off California which suggest limited movements between areas. Differences in pupping seasonality between various areas on the west coast (Bigg 1969b) also imply more than one population (Temte et al. 1991). Burg (1996) recently examined mitochondrial and microsatellite data from animals throughout British Columbia and in southeast Alaska, and concluded that evidence suggests population segregation. Based on pigmentation patterns and dentition, suggestions of population discreteness have been made for Harbour Seals on Sable Island (Boulva and McLaren 1979), though recent microsatellite data from Sable Island (Coltman, Bowen and Wright, unpublished, cited in Whitehead et al. 1998) suggest mixing with mainland populations.

Protection

International

Harbour Seals are not listed under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), thus international trade is not monitored or regulated.

National

Canada: Two factors are important in the protection of a species, the legal system in place which prohibits or regulates hunts or kills, and the system of monitoring and enforcement of the regulations or rules which exist. In Canada, management authority for Harbour Seals lies with the federal Department of Fisheries and Oceans through the Marine Mammal Regulations of 1993 (promulgated under the Fisheries Act of Canada, 1867). These regulations theoretically control the hunting of this species in Canadian waters. All individuals except aboriginals are required to obtain a "Fishing Licence" to hunt seals, and fees for such a licence are low (\$5). Issuance of licences is at the discretion of the Minister of Fisheries and Oceans, but for Harbour Seals, all areas are currently closed for hunting (Marine Mammal Regulations; J. Conway, personal communication). D. Petrachenko (in litt.) notes that Fisheries and Oceans has issued licences to aboriginals in British Columbia for a small scale harvest. In Arctic regions all hunting is likely to be by aboriginals (who do not require licences), thus no protection appears to be in place. In British Columbia, aquaculture operators are permitted to kill nuisance animals around their net pens (D. Petrachenko, in litt.). Some nuisance animals were killed at aquaculture operations in New Brunswick as part of a pilot licencing

system, but such killing is currently prohibited (J. Conway, personal communication). "Disturbance" is also prohibited through these regulations, except when hunting under licence. The operation of aircraft within 600 m of any live seal on land is also prohibited. Smith (1997) notes that freshwater seals north of the 55th parallel are listed as protected under the James Bay and Northern Quebec agreement, but that this protection does not have the force of law. Some haul-out and breeding sites are protected from development by both provincial and federal governments through provincial parks and/or ecological reserves as well as federal parks (such designations also provide limited protection from land-based disturbance).

In terms of monitoring or enforcement of regulations, little information is available. Disturbance of animals regularly occurs at haulout sites by boats, planes, and people on land (Baird, personal observations), and no monitoring or enforcement action is taken. As well, there have been numerous reports of illegal shooting of animals around aquaculture operations on the west and east coasts, as well as shooting by fishermen, though no prosecutorial action has been taken (H. Breen, J. Conway, D. Tobin, personal communication). Such a lack of monitoring or enforcement of these regulations leaves their effectiveness in question.

United States: Killing or disturbance of Harbour Seals in the United States is prohibited under the Marine Mammal Protection Act.

Greenland: Since 1960, hunting of adult Harbour Seals in Greenland has been prohibited from May through September. Some specific regions have more restrictive regulations, with hunting of adults completely forbidden. Restrictions have been recently reviewed by Teilmann and Dietz (1994).

Population Numbers, Sizes and Trends

Populations on both the Pacific and Atlantic coasts of Canada were substantially reduced due to long-term bounty or culling programs and/or commercial hunts (Bigg 1969a; Boulva and McLaren 1979; Olesiuk et al. 1990a), which ended in the late 1960s and early 1970s (1969 in British Columbia, 1976 in the Atlantic). On the Pacific coast of Canada, the Harbour Seal is the most abundant marine mammal in the province, and the population has been increasing since the end of culling and may be near original levels (Olesiuk et al. 1990a). The most recent published data from British Columbia (from 1988) suggests the population was between 75 000 and 88 000 animals. The trend in population growth at that time suggested a continued increase (Olesiuk et al. 1990a), though Smith (1994) noted that there is some indication from recent surveys that the increase is beginning to level off. Between 1973

and 1988, the British Columbia population was estimated to increase at about 12.5% per year (Olesiuk et al. 1990a).

Populations which border British Columbia appear to be increasing or stable. From 1978 through 1993, counts of Harbour Seals in the neighboring waters to the south, in Washington state, increased at an average rate of almost 8% (Huber 1995); surveys from neighboring waters to the north, in southeast Alaska, have generally shown increases or stable populations (Hill et al. 1997).

Off Canada's east coast, information on population sizes or trends is less complete. Numbers from eastern Canadian waters south of Labrador in 1973 were estimated by Boulva and McLaren (1979) using questionnaire surveys, interviews and distribution of bounty kills. The total population off eastern Canada at that time was estimated to be 12 700 individuals, with some local areas showing decreasing numbers and other areas having stable numbers. Stobo and Fowler (1994) present data from aerial surveys in the Bay of Fundy and off southwest Nova Scotia from 1985–1987 and from 1991–1992, and suggest that Harbour Seal abundance has increased between those periods. However, the rate of growth and current population size for that area is unknown (Stobo and Fowler 1994). In the late 1980s, the Sable Island population was the largest in eastern Canada. However, numbers of animals on Sable Island have decreased drastically in recent years (D. Bowen, W. Stobo, personal communication; Ellis 1998). Trends in the number of pups born on Sable Island between 1978 and 1996 have been presented by Ellis (1998). The number of pups born annually have shown a steady decline since 1989, when about 600 pups were born, through to 1997, when only 30 pups were born (Ellis 1998; D. Bowen, personal communication), and the number of adults of both sexes has also dramatically declined (Ellis 1998). Causes of this decline are unknown, but could include predation by sharks, competition with Grey Seals, and/or movements of individuals away from Sable Island (D. Bowen, W. Stobo, personal communication; Ellis 1998). Recent (1994) information on Harbour Seals in the St. Lawrence Estuary has been provided by Lesage et al. (1995b). A total of 389 Harbour Seals were counted, but it is unclear what proportion of the population this count represents. While this number is substantially lower than the 710 seals estimated to live in the area in 1973 (Boulva and McLaren 1979), Lesage et al. (1995b) note that differences in methods between the two studies make any direct comparison impossible. Some distributional data, from a mail-out survey to fishermen, was recently collected for Prince Edward Island (D. Cairns, Department of Fisheries and Oceans, PEI, personal communication). No recent information on Harbour Seals in Newfoundland, Labrador or the outer Gulf of St. Lawrence has been

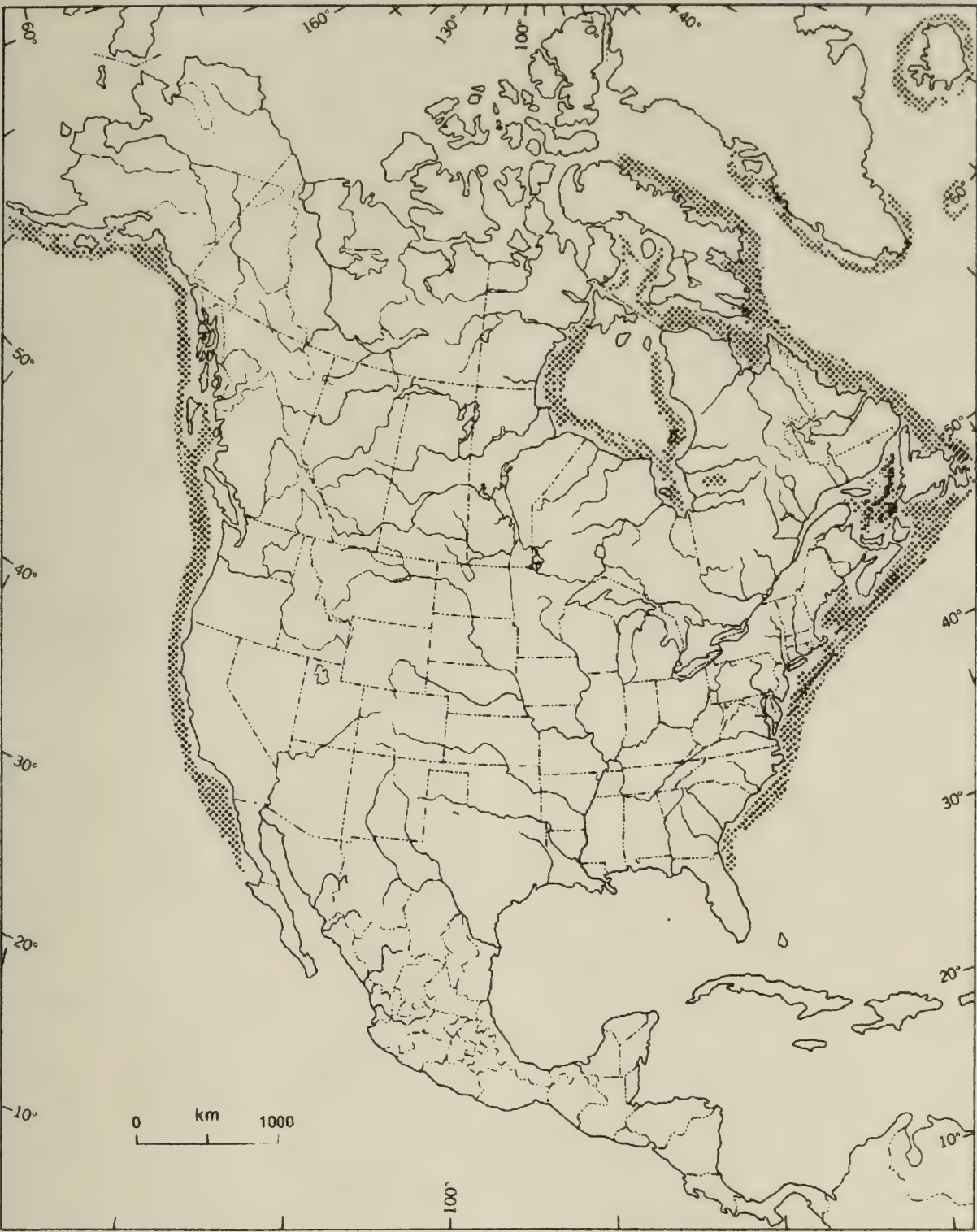


FIGURE 3. Distribution of Harbour Seals in Canadian waters.

collected (J. Lawson, J. Lien, G. Stenson, personal communication).

No substantive information is available regarding population size or trends of Harbour Seals in the Canadian Arctic (though see Remnant 1997 for a recent assessment of numbers in the Lower Churchill River).

On the east coast there are three countries/territories which likely exchange Harbour Seals with

Canadian populations: the United States, Greenland, and the French islands of St. Pierre and Miquelon. The Harbour Seal population in adjoining U.S. waters appears to be increasing, with an 8.7% annual rate of increase in Maine coastal waters based on counts between 1981 and 1993 (Kenney and Gilbert 1994; Waring et al. 1997). In Greenland, Teilmann and Dietz (1994) report an apparent decline in Harbour Seals numbers over the last 100 years, and

suggest that hunting may have been the primary cause for this decline. Harbour Seal numbers at the French islands of St. Pierre and Miquelon, off the south coast of Newfoundland, appeared to increase between 1970 and 1982 (Ling et al. 1974; Davis and Renouf 1987), but no recent information is available.

Habitat

Like all pinnipeds, Harbour Seals utilize both aquatic and terrestrial habitats. In terms of aquatic habitats, Harbour Seals are generally a near-shore, coastal species, though movements in pelagic waters have been documented (Beck 1983). As noted above, Harbour Seals also inhabit fresh-water systems and may spend considerable time in river estuaries. Use of the aquatic environment, i.e., which areas of the water column Harbour Seals tend to use most, may differ depending on time of year (breeding versus non-breeding, or in response to local concentrations of prey), sex (since males during the breeding season may remain closer to breeding sites; e.g., Coltman et al. 1997; Van Parijs et al. 1997), and location, due to bathymetry, or since predation pressure may differ between east and west coasts of Canada, thus affecting diving behaviour (cf. Le Boeuf and Crocker 1996). In the Arctic, Mansfield (1967) noted that Harbour Seals are largely restricted to areas of high current flow where the surface is kept clear of ice.

In terms of terrestrial habitats used, Harbour Seals haul out on both sand and rock substrates, usually on isolated rocks or islets (without land-based predators), on sand bars, and occasionally in small sea caves, including some on large islands with terrestrial predators, e.g., Vancouver Island. Harbour Seals also make use of man-made structures such as log booms and recreational floats for pupping and hauling out (e.g., Cottrell 1995; Figure 2). In some areas (e.g., southeast Alaska) Harbour Seals will also pup on ice calved off tidal glaciers (e.g., Matthews 1995). Areas used for pupping are also used during the non-breeding season as haul-out sites. Age- and sex-based segregation occurs at some haul-out sites, and may vary according to season (e.g., Allen et al. 1988; Kovacs et al. 1990; Whitman and Payne 1990). Understanding which factors influence hauling out behaviour is important both for calibrating surveys (e.g., Olesiuk et al. 1990), as well as for understanding how disease transfer at haulout sites might be influenced by environmental fluctuations (Lavigne and Schmitz 1990; Grellier et al. 1996). A number of factors seem to influence hauling out behaviour, including haul-out substrate, tide height, time of year (relative to breeding and moulting periods), time of day, temperature, wind speed, precipitation, cloud cover, the occurrence of storms, disturbance, El Niño events, and location (Boulva and McLaren 1979; Pauli and Terhune 1987a, 1987b; Yochem et al. 1987; Watts 1992, 1993; Grellier et al.

1996; Hanan 1996), thus it seems that location-specific studies are needed for developing survey calibration factors. Use of land-based sites is typically restricted to a few tens of meters from shore (though see exception above in Distribution and Movements).

General Biology

Harbour Seals can be quite gregarious on land (Figure 4). Olesiuk et al. (1990) note a mean haul-out size in the Strait of Georgia of about 22 individuals, but groups of several thousand have been recorded (Bigg 1981). While in groups Harbour Seals typically maintain some distance between individuals (Sullivan 1982).

Harbour Seals give birth to a single pup, and have a clearly defined pupping season that typically lasts one to two months in any particular area (Bigg 1981). Timing of pupping varies geographically (Bigg 1969b; Temte et al. 1991), but generally occurs between May and July. Unlike most other phocids, Harbour Seal pups follow their mothers into the water within hours of birth (Lawson and Renouf 1985). Pups on Sable Island are weaned at 24 days of age (Muelbert and Bowen 1993), and females come into estrous within two weeks after weaning (Bigg 1969a). Females mature at between 3 and 6 years of age, with most maturing by 5 years (Bigg 1969a). Mortality rates have recently been summarized by Heide-Jorgensen and Harkonen (1988). Mortality of animals in the first year can be quite high, ranging from 0.20 to 0.60. For individuals older than one year, annual mortality ranges between 0.05 and 0.20, and males older than five years show higher mortality than females (e.g., Pitcher 1990). Maximum recorded longevity is 32 years of age (Pitcher and Calkins 1979).

While numerous studies have been undertaken on the diet of Harbour Seals in Canadian and adjoining waters, characterization of the diet is exacerbated by biases in techniques to study diet (Harvey 1989; Cottrell et al. 1996), as well as strong seasonal, geographical, age and habitat-based variation (Bigg 1973; Bigg et al. 1990; Olesiuk 1993; Cottrell 1995; Bowen and Harrison 1996; Iverson et al. 1997; Tollit et al. 1998). In general, Harbour Seals have an extremely diverse diet (Bigg 1981), usually taking advantage of locally abundant prey. In the Strait of Georgia, Pacific Hake (*Merluccius productus*) and Pacific Herring (*Clupea pallasii*) account for 75% of the diet both in terms of energy and biomass, while Salmon (*Oncorhynchus* spp.), Plainfin Midshipman (*Porichthys notatus*), Lingcod (*Ophiodon elongatus*) and others comprise the remaining prey (Olesiuk et al. 1990b; Olesiuk 1993). Their tendency to move into river mouths following salmon runs (Fisher 1952; Bigg et al. 1990; Cottrell 1995) has caused considerable conflict with fishermen. Off eastern Canada, recent work by Bowen and Harrison (1996)



FIGURE 4. Group of Harbour Seals on sandy beach at Smith Island, Washington State. Photo by the author.

in two areas off Nova Scotia and New Brunswick suggest that Atlantic Herring (*Clupea harengus*), Atlantic Cod (*Gadus morhua*), Polluck (*Pollachius virens*), and Short-finned Squid (e.g., *Illex illecebrosus*) appear to comprise the majority of prey. Bowen and Harrison (1996) document geographic and inter-annual variability in prey taken in their study, and other evidence also suggests strong geographic or temporal variation. For example, Payne and Selzer (1989) note that American Sandlance (*Ammodytes americanus*) dominated the diet of Harbour Seals off Cape Cod, and a small sample of stomach contents from Sable Island examined by Walker and Bowen (1993) contained only Sandlance. Little has been reported on their diet in Arctic waters, though Beck et al. (1970) report stomach contents of one individual taken in fresh water, which contained Lake Trout (*Salvelinus namaycush*) and Whitefish (*Coregonus clupeaformis*).

Sources of Mortality and Potentially Limiting Factors

Potentially limiting factors can be from either anthropogenic or natural sources. Such factors could either directly or indirectly cause the death of animals, or result in decreased reproductive rates. Anthropogenic factors which may contribute to population declines or limits include: incidental mortality in fisheries, direct killing (illegal or permitted culling associated with aquaculture operations and

fisheries, as well as small-scale harvesting by natives), oil spills, accumulation of persistent toxins, disturbance at breeding colonies by tourism, coastal development, vessel traffic or researchers, displacement from feeding or breeding areas by acoustic harassment (e.g., high amplitude seal "scarers" at aquaculture operations), and depleted food sources from competition with human fisheries.

Historically Harbour Seal populations in both eastern and western Canada were drastically reduced from direct kills in both control or bounty programs and/or for harvesting of pelts (Bigg 1969a; Boulva and McLaren 1979). Re-initiation of such bounty or culling programs have frequently been suggested by fishing groups, in response to perceived or actual conflicts with fisheries. In British Columbia, direct takes occur from a number of sources. In terms of harvesting by natives, Fisheries and Oceans Canada has issued licences for a coast-wide harvest totaling less than 100 individuals (D. Petrachenko, in litt.). Aquaculture operations in both eastern Canada and British Columbia are licenced to shoot nuisance seals. In British Columbia a total of about 500 Harbour Seals are reported to be killed annually under these permits (D. Petrachenko, in litt.). However, reports of substantial illegal kills at aquaculture operations suggest that the number killed may be much greater (H. Breen, personal communication). In 1997 Fisheries and Oceans Canada undertook a small cull (approximately 25 seals) in one

area on the British Columbia coast. Levels of direct takes in Arctic and eastern Canadian waters are unknown. Remnant (1997) notes that some hunting of seals occurs in the freshwater portion of the Churchill River, and that Manitoba Natural Resources annually harvests some seals in the same area for bait for live-trapping Polar Bears (*Ursus maritimus*). I. McLaren (personal communication) noted that pelts of Harbour Seals are prized by Arctic hunters, and Mansfield (1967) stated that given the extremely localized distribution of Harbour Seals in Arctic waters, this species is an easy target for native hunters, and their "future [is] somewhat precarious".

Harbour Seal bycatch in gillnet fisheries has been well-documented in California, Washington and Alaska (Barlow et al. 1994; Read 1994), but little information is available from Canadian waters, probably due to the lack of observer programs on fishing vessels. Reports have been made of Harbour Seals being taken on longlines in eastern Canada, and such seals drown, since the lines are weighted to the bottom (W. Stobo, personal communication). Harbour Seal mortality in the Smelt cage fishery off Prince Edward Island have also been reported (P.-Y. Daoust, personal communication). Off Norway, Bekkby and Bjorge (1998) suggest that mortality in fishing gear may control population growth, thus some effort in assessing mortality in fishing gear in Canadian waters is probably warranted. Hooking of Harbour Seals on sports fishing lines also occurs (R. Bates, personal communication). While it seems unlikely these animals are directly killed as a result, retention of hooks and trailing lines in the digestive tract of Harbour Seals could cause problems associated with feeding or infection.

In heavily-populated areas, pups are occasionally "kidnapped" by well-meaning people who assume they have been abandoned, while a mother is out foraging or when she is disturbed into the water by approaching humans. Such pups are often raised at rehabilitation facilities and released back into the wild, but little information is available on survival rates. Vessel collisions with Harbour Seals do occur in Canadian waters (K. Langelier, personal communication), though there is no information to assess how frequently such collisions occur or whether they always result in death. A. Morton (personal communication) has noted an increase in the frequency of vessel collisions in one area on the British Columbia coast, which has corresponded with the initiation and use of high-intensity acoustic harassment devices at nearby aquaculture operations (suggesting that Harbour Seals might be deafened by such devices). Disturbance of Harbour Seals at pupping or haul out sites, resulting in sudden movement of all hauled-out animals into water, occurs regularly in some areas (e.g., Kovacs et al. 1990). Such disturbance may potentially result in separation of mothers and pups,

as well as injury of individuals, or increased vulnerability to predation by sharks or killer whales, due to increased time in the water. There are numerous sources of such disturbance, including close approaches by private or commercial vessels engaged in fishing, wildlife viewing, or transiting through an area, overflights by aircraft (military and private), and approaches by dogs or people on land (including researchers). In one area, Race Rocks, at the southern tip of Vancouver Island, military activity at a site used for explosive testing regularly results in disturbance of hauled out seals. No information is available to estimate the magnitude of the impacts of disturbance on Harbour Seals in Canada, but its effects may not be trivial. For example, Johnson (1977) estimated that overflights by aircraft may have been responsible for the deaths of 10% of approximately 2000 Harbour Seal pups born on an island in Alaska in 1976. A review of Harbour Seal reactions to aircraft and other sources of disturbance is presented in Richardson et al. (1995).

The role of contaminants in immunosuppression of Harbour Seals and other marine mammals has received considerable attention in recent years (e.g., Ross et al. 1995, 1996, 1997; see also Schandorff 1997a, 1997b). As a result of captive studies which demonstrated that ambient contaminant levels in Baltic Sea herring were immunotoxic when fed to Harbour Seals, it is now thought that the 1988 Morbillivirus-associated mass mortality among northern European Harbour Seals may have been exacerbated by contaminants (Ross et al. 1996, 1997; de Swart et al. 1996). From the British Columbia coast, Ross et al. (1998) report on levels of a number of contaminants (PCBs, PCDDs and PCDFs) in Harbour Seals, and note that 2 of 24 recently weaned pups sampled had levels higher than those found to produce immunotoxicity in captive Harbour Seals. Ross (personal communication) also notes that male Harbour Seals above about seven years of age in the Strait of Georgia also have levels above the point which produces immunotoxicity. Given the exponential rate of increase of the Harbour Seal population on much of the British Columbia coast (Olesiuk et al. 1990), it is clear that such toxins do not have a substantial impact on reproduction or longevity, although their potential role in mass mortalities (and the huge impacts such mortalities may have on population size, see below) does warrant concern.

The wide-spread distribution of Harbour Seals along Canada's coasts make them less likely to be seriously impacted on a population level by an oil spill than species whose distributions are more limited. However, their habit of hauling out in inter-tidal areas would bring them into direct contact with spilled oil, and spills (and related spill cleanup activities) occurring during pupping periods could have the potential to result in separations of mothers and offspring. Frost

et al. (1994) discuss a variety of impacts on Harbour Seals from a major oil spill in Prince William Sound, Alaska, and conclude that seals became coated with oil, oil was incorporated into tissues, seals behaved abnormally, and pathological damage occurred. Comparisons of counts within Prince William Sound before and after the spill showed a significant decline in numbers at oiled sites compared to non-oiled sites (Frost et al. 1994).

Indirect effects including competition with human fisheries may be important, though little information is available to assess such threats (see Baird et al. 1992; Lavigne 1995; Trites 1997). Thompson et al. (1997) note that in times of shortages of preferred prey, switches to alternate prey items may result in haematological changes leading to anemia.

A number of natural sources of mortality have been identified, including predation, separation of dependent pups from their mothers, injury during storms, and diseases. Predation by Killer Whales (*Orcinus orca*) and sharks has long been known as a source of mortality (Scheffer and Slipp 1944). Mortality due to predation may be quite high in some areas. Harbour Seals appear to be the primary prey taken by "transient" Killer Whales around southern Vancouver Island (Baird and Dill 1996), and Watts (1996) noted that an individual seal may face a 50-80% chance of being eaten by a Killer Whale before reaching reproductive age. Off Sable Island, Nova Scotia, sharks are thought to be a major source of mortality (Beck 1983; Ellis 1998; W. Stobo personal communication). Some predation by Northern Sea Lions, *Eumetopias jubatus* (Pitcher and Fay 1982) as well as Coyotes (Steiger et al. 1989) has been documented, and aggression by Northern Elephant Seals (*Mirounga angustirostris*) towards Harbour Seals has been seen at one site in California (Mortenson and Follis 1997). Interspecific competition with other rapidly increasing pinniped populations may also influence population growth (Hanan 1996). Injury during storms has been reported as a source of injury (Wilke 1943), and separations of mothers and pups during storms can be quite frequent (Boness et al. 1992). Pup mortality may also increase during El Niño events (Koons 1998). Disease outbreaks, including phocine distemper virus and influenza (Geraci et al. 1982; Hinshaw et al. 1984; Osterhaus and Vedder 1988; Duignan 1995), have been responsible for large-scale die-offs in some areas (e.g., North Sea and New England). The die-off in the North Sea in 1988 resulted in a population reduction of over 50%. Such die-offs are clearly unpredictable, but given their magnitude and apparently increasing frequency of occurrence, they must be taken into account in conservation planning and population viability analyses (Young 1994; Simmonds and Mayer 1997).

Special Significance

In some areas of Canada (e.g., British Columbia and the Bay of Fundy) Harbour Seals are important components of commercial wildlife viewing excursions, and thus contribute economically to tourism, although the level of economic input from such tourism has not been quantified. Since Harbour Seals co-inhabit many developed coastal regions in Canada, they are often frequently viewed by residents and may be given considerable aesthetic value as an important component of the natural environment. Conversely, due to actual or perceived conflicts with fisheries in many parts of country, Harbour Seals (and other pinnipeds) are viewed primarily as a pest. As a species which appears to show considerable site-fidelity, feeds relatively high on the food web, and lives for relatively long periods, they may also be viewed as a potential indicator species in the marine environment (Calambokidis et al. 1991). One population in Canada, at Sable Island, is unique, being the only truly offshore breeding population of this species in the world (Whitehead et al. 1998).

Evaluation

Based on the large population and evidence of increasing trends in numbers (Olesiuk et al. 1990a), the Pacific coast population of Harbour Seals should probably be classified as Not at Risk (NAR) by COSEWIC. However, recent evidence of contaminant levels high enough to cause immunosuppression (Ross et al. 1998), and reports of high levels of illegal kills (H. Breen personal communication) both warrant further study, as does the potential impact of overfishing or natural fluctuations in prey populations on Harbour Seal population dynamics. No one is doing research to establish the present status of Harbour Seals in the Canadian Arctic, including Hudson Bay and James Bay, because they have little economic importance (P. Richard, personal communication). Yet, they are more vulnerable to overexploitation than other species because they live in small sedentary pockets of population (P. Richard, personal communication).

For the same reason (ie., lack of economic importance), little is known about the status of Harbour Seals off Labrador, Newfoundland, the outer Gulf of St. Lawrence, or off mainland Nova Scotia. The population which has received the most research attention off eastern Canada, at Sable Island, has drastically declined in recent years, although the causes are unknown. Insufficient information is available to assess the status of eastern Canadian or Arctic populations, and these populations should be classified as Indeterminate by COSEWIC.

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Status of Killer Whales, *Orcinus orca*, in Canada*

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Killer Whales can be found in all three of Canada's oceans, as well as occasionally in Hudson Bay and in the Gulf of St. Lawrence. Little is known about their occurrence or biology in the Atlantic or Arctic, but Killer Whales appear to be uncommon in most parts of these areas. In the Canadian Arctic and western Atlantic small numbers were killed historically in commercial whaling operations (or shot incidentally to such operations), and small numbers have been documented taken by natives. Predictable concentrations of killer whales are found in British Columbia, and populations in British Columbia's nearshore waters are among the most well-known populations of cetaceans world-wide. Killer whales off the Pacific coast can be classified into two distinct "types" or "forms" (termed *residents* and *transients*), which differ in diet (*residents* feed on fish, *transients* feed on marine mammals), morphology, genetics and behaviour. The exact taxonomic relationship between these two types is unclear, though some authors have termed them "races", others consider them separate species. Regardless, from both a scientific and management perspective these populations should be treated as distinct. Within British Columbia waters *residents* appears to be sub-divided into three geographic communities or populations (termed the "northern" and "southern" *residents*, and "offshore" killer whales), based on association patterns, genetics and morphology. Relatively little is known of the "offshore" population of Killer Whales. All populations (including *transients* and the three *resident* populations) are small (in the low hundreds), and have low potential rates of increase. No trend information is available for "offshore" or *transient* killer whales. The "northern" *resident* population has been growing steadily in size since the 1970s (when live-capture fisheries stopped and shooting declined), while the "southern" *resident* population has been growing only sporadically, and is currently smaller than the pre-live-capture population estimate from the 1960s. Given the small population sizes and their low potential rates of growth, Killer Whales are potentially at risk from anthropogenic influences in two primary ways: due to immunotoxic affects of persistent toxic chemicals (levels in "southern" *residents* are three times higher than levels known to cause immunotoxicity in harbour seals), and due to a reduction in prey availability. It is also possible that the large and growing commercial and recreational whale watching industry on the west coast may be having an impact, though such impacts are as yet unclear. In terms of natural factors, periodic events such as mass strandings or entrapments in narrow inlets or ice have the potential to drastically reduce local populations. Since virtually all of these factors should impact Killer Whales throughout Canadian waters, all populations, at the least, should be considered vulnerable, that is, as "species of special concern because of characteristics which make them especially sensitive to human activities or natural events". As the "southern" *resident* population is extremely small (89 individuals in 1998), has declined by 10% in the last three years due to an increase in mortality rates (primarily of adult females), is more subject to anthropogenic influences than other populations, and these influences are not expected to decrease in the foreseeable future, it should be listed as threatened by COSEWIC. Further research, particularly on Arctic, Atlantic and "offshore" populations, is clearly needed.

Key Words: Killer Whale, *Orcinus orca*, Epaulard, Canada, British Columbia, status, cetacean, sympatric populations.

The Killer Whale or épaulard, *Orcinus orca* (Linnaeus 1758) is found in all three of Canada's oceans (Figure 1). In the Pacific they are the most well-known cetacean both to the scientific community and to the general public. In fact, off the British Columbia coast long-term studies of Killer Whales have led to a

greater understanding of these animals than of almost any other species of cetacean (Baird 2000). In the Canadian Arctic and Atlantic, Killer Whales are seen only occasionally and no in-depth scientific studies have been undertaken. Yet, because of their relatively large size, distinctive appearance, and the publicity this species has garnered in books, magazine articles, television, and in aquaria, Killer Whales are known by and recognizable by virtually everyone. In this report I review what is known of the general biology and ecology of Killer Whales in Canadian waters, including population discrimination, sizes and trends, behaviour, life history and limiting factors. Gaps in the available data are identified that may be relevant to their long-term status assessment. This review has been undertaken on behalf of the Fish and Marine Mammal Subcommittee of COSEWIC, the Committee on the Status of Endangered Wildlife in Canada.

*Reviewed and approved by COSEWIC, April 1999 — status assigned North Pacific "resident populations" Threatened, North Pacific "transient" populations Vulnerable, North Atlantic and Arctic populations Indeterminate.

Status reviewed again by COSEWIC, November 2001 — status assigned "southern resident" population Endangered, "northern resident" population Threatened, NE Pacific offshore population special concern, Northwest Atlantic (Eastern Arctic populations Data Deficient).

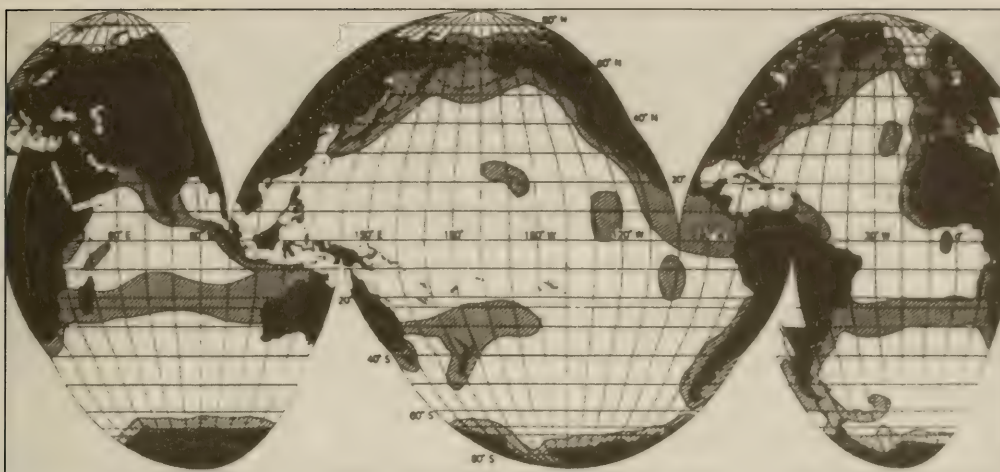


FIGURE 1. Map showing world-wide distribution of Killer Whales. Shaded areas indicate records of sightings or strandings; however unshaded areas may be part of the normal range with no sightings documented. Map courtesy of Marilyn Dahlheim, National Marine Mammal Laboratory, NMFS, Seattle.

Description

The distinctive black and white pattern, blunt head, and tall dorsal fin in the middle of the back, are the primary identifying characteristics of Killer Whales (Figure 2). Adult males are substantially larger than females, although very few accurate measurements are available. Reports of maximum lengths of 9.75 m for males and 8.53 m for females given in the literature (e.g., Perrin and Reilly 1984) are actually estimates. The maximum length measured for males and females is 9.0 m and 7.7 m, respectively (Heyning and Brownell 1990). There is some suggestion of differences in size for individuals from different populations (cf. Berzin and Vladimirov 1983; Heyning and Brownell 1990), and more accurate measurements from different parts of their range are needed before average lengths of individuals from any one population can be charac-

terized. From the few measurements available for adult individuals from British Columbia (e.g., Bigg and Wolman 1975), it is clear that the average length of adult individuals is much smaller than the maxima noted above. Adults are sexual dimorphic in appendage size, with adult males having a tall triangular dorsal fin which may reach up to 1.8 m in height, while in juvenile males and adult females it reaches 0.9 m or less and is generally more falcate (Figure 3). Pectoral fins and tail flukes are also sexually dimorphic, being much larger in adult males, with the fluke tips also bending downwards. As well, pigmentation in the genital area differs between males and females (Bigg et al. 1987).

Population Discrimination

The question of population segregation or division (fragmentation) is critical to any evaluation of status (IUCN 1996). If more than one distinct population exists, and factors which affect each population differ in any way, then each population must be monitored and managed independently.

"Residents" and "Transients"

In the case of Killer Whales in the Canadian Arctic and North Atlantic, no information is available to assess whether any population differentiation has occurred (Mitchell and Reeves 1988; Anonymous 1993). For the Pacific coast of Canada, clear evidence is available for differentiation of Killer Whales into two distinct "types" or "forms", termed "resident" and "transient" (Table 1; Figure 4; Bigg et al. 1976). The names "resident" and "transient" have become entrenched in the literature even though it has been demonstrated that they are not accurate as descriptions of the site fidelity and movement patterns of the two forms (Guinet 1990; Baird et al. 1992). As the names are frequently mis-interpreted as descriptive categorizations, they are referred to



FIGURE 2. An adult female *transient* Killer Whale porpoising off Victoria, British Columbia, showing the main features for identification; the striking black and white colouration, a blunt head and a tall, centrally-placed dorsal fin. Photo© by the author.



FIGURE 3. Photograph of two *transient* Killer Whales off Victoria, British Columbia, showing the clear sexual-size dimorphism, with the male (right) having a tall, straight dorsal fin and the female (left) having a shorter, falcate, dorsal fin. Photo© by the author.

hereafter as *resident* and *transient* to try to prevent such confusion.

Several studies have documented a variety of behavioural, ecological, morphological and genetic differences between *transients* and *residents* (Table 1; Bigg et al. 1987; Baird and Stacey 1988; Morton 1990; Baird et al. 1992; Baird and Dill 1995, 1996; Barrett-Lennard et al. 1996; Hoelzel et al. 1998; Matkin et al. 1998; Ford et al. 1998). One of the most important differences is diet; *residents* appear

to feed almost entirely on fish, while *transients* appear to feed almost entirely on marine mammals (for more detailed discussion, see Feeding Habits, below). Association patterns, in terms of observations of individuals traveling together in a group, and vocal dialects, are also used to discriminate *residents* from *transients* (Black et al. 1997). Interactions between *residents* and *transients* have only been reported on a small number of occasions (Jacobsen 1990; Morton 1990; Barrett-Lennard 1992; Baird

TABLE 1. Characteristics which differ between *resident* and *transient*-type Killer Whales in the nearshore waters of the eastern North Pacific.

MORPHOLOGY/GENETICS

- Shape of the dorsal fin (Bigg et al. 1987; Bain 1989)
- Saddle patch pigmentation (Baird and Stacey 1988)
- Possibly eye patch pigmentation (D. Ellifrit, personal communication, cited in Baird 1994)
- Mitochondrial and nuclear DNA (Stevens et al. 1989; Hoelzel and Dover 1991; Hoelzel et al. 1998; Matkin et al. 1998)

BEHAVIOUR/ECOLOGY

- Diet (Bigg et al. 1987; Morton 1990; Baird and Dill 1996; Ford et al. 1998)
- Travel patterns/habitat use (Heimlich-Boran 1988; Morton 1990; Baird and Dill 1995)
- Respiration patterns (Morton 1990)
- Vocalizations (Ford and Hubbard-Morton 1990; Morton 1990)
- Echolocation (Barrett-Lennard et al. 1996)
- Amplitude of exhalations (Baird et al. 1992; Baird 1994)
- Possibly diving patterns (Baird 1994)
- Group size (Bigg et al. 1987; Morton 1990; Baird and Dill 1996)
- Pattern and extent of natal philopatry (Bigg et al. 1987; Baird and Dill 1996; Baird and Whitehead 2000)
- Seasonal occurrence (Guinet 1990; Morton 1990; Baird and Dill 1995)
- Geographic range (Bigg et al. 1987)



FIGURE 4. Morphological differences between *residents* (left) and *transients* (right) include differences in dorsal fin shape (with *residents* typically having more rounded fins) and saddle patch pigmentation patterns (with *transients* typically having less complex patterns). Overlap in the characteristics exist, so they cannot always be used to distinguish type. Photos© by the author.

and Dill 1995). On eight of those occasions no change was recorded in the behaviour of either form as they passed within a couple of kilometers of each other. *Transients* have been seen changing direction away from *residents* (avoiding them) on eight occasions, *residents* avoiding *transients* twice, and both avoiding each other twice. Since *residents* vocalize more frequently than *transients* (Morton 1990; Barrett-Lennard et al. 1996), *transients* may detect the presence of *residents* much sooner, and more frequently than the other way around (Baird and Dill 1995). Cases of *residents* showing no reaction when near *transients* may be due simply to them being unaware that *transients* were nearby. One observation of aggression between the two forms involved a large group of *residents* attacking a small group of *transients* (Ford and Ellis 1999), and one other observation of apparent aggression has also been observed (P. Spong, H. Symonds, personal communications).

The exact taxonomic relationship of these two forms is unclear. Bigg et al. (1987) termed these two types of Killer Whales "races", and this term has been adopted, uncritically, by many investigators. "Races" are usually defined in a geographic sense, implying geographically isolated populations which are typically given subspecific designation (Mayr and Ashlock 1991). Baird et al. (1992) outlined how these two forms may have evolved, and termed them incipient species. Baird (1994) subsequently argued that they should be considered separate species, although no formal description of each species has

been presented. Heyning and Dahlheim (1993) have argued that insufficient information is available to determine the level of isolation between them. Hoelzel (personal communication) estimated genetic migration between these two forms at one male per five generations and one female per 20 generations (see Hoelzel et al. 1998).

Regardless of such disagreements and uncertainty in taxonomic relationship between these two forms, there is sufficient evidence to suggest that these forms or types should be treated as separate populations for management. Considering the differences in behaviour and ecology which have been documented (e.g., Table 1), it is also prudent not to apply behavioural or life history characters from one form to another, nor indeed from these populations of Killer Whales to Killer Whales elsewhere.

The suggestion that there may be more than one species in the genus *Orcinus* is not new. Mikhalev et al. (1981) and Berzin and Vladimirov (1983) described two species in the Southern Ocean, *O. nanus* and *O. glacialis*, respectively, both of which seem to refer to the same population of smaller individuals (Heyning and Dahlheim 1988). As well as differences in body size, other differences in morphology, behaviour and diet were noted, with one species feeding primarily on fish and the other feeding primarily on marine mammals, similar to the situation off Canada's west coast (Berzin and Vladimirov 1983). Neither of these species designations have been generally accepted (Perrin 1982; Heyning and Dahlheim 1988).

"Southern", "Northern" and "Offshore" Residents

A further level of population differentiation appears to exist within the *resident* form. Based on association patterns, pigmentation patterns and genetics, *residents* within British Columbia appear to be divided into three distinct, largely geographically based communities or populations (Bigg et al. 1987; Baird and Stacey 1988; Bain 1989; Ford et al. 1994a; Hoelzel et al. 1998; Matkin et al. 1998). One population, found generally around southern Vancouver Island and in Washington state, has been termed the "southern" *resident* community, one found generally off northern Vancouver Island and in southeast Alaska has been termed the "northern" *resident* community, and a third putative *resident* population is termed "offshore" Killer Whales, which appear to inhabit offshore waters along the entire coast. It should be noted that while based on mitochondrial DNA "offshore" Killer Whales are closely related to northern and southern *residents* (Hoelzel et al. 1998; Matkin et al. 1998), relatively little is known about other aspects of their biology, and it is unclear whether "offshore" Killer Whales share behavioural or ecological characteristics with northern or southern *residents*. British Columbia northern *residents* have been observed associating, and share the same mitochondrial DNA haplotype, with other *resident*-type Killer Whales in southeast Alaska (Dahlheim et al. 1997; Hoelzel et al. 1998). The *resident*-type whales from Alaska have not been documented in British Columbia, but based on both association patterns and genetics are likely part of the same population. These southeastern Alaska *residents* have in turn been observed interacting with *residents* in Prince William Sound, Alaska (Matkin et al. 1997), suggesting that gene-flow between northern *residents* and these other whales may exist. Similarly, both "offshore" Killer Whales and *transients* documented in British Columbia have also been seen off Alaska, Washington and/or California (Dahlheim et al. 1997; Black et al. 1997), suggesting that these individuals are part of larger populations. The U.S. National Marine Fisheries Service evaluates each of the *resident* populations, and the *transient* population, independently (Barlow et al. 1997; Hill et al. 1997).

The northern and southern *resident* communities have been reported to have ranges which do not overlap (e.g. Bigg et al. 1990; Felleman et al. 1991), but there are data which indicate their ranges overlap by over 120 km on both the east and west coasts of Vancouver Island (Bigg et al. 1976; M. A. Bigg, personal communication 1990; Ford et al. 1994a). "Offshore" Killer Whales similarly overlap in range with both northern and southern *residents*, though observations of "offshore" Killer Whales in or near the core areas of the other two groups are rare (e.g., Walters et al. 1992; Ford et al. 1994b*). Regardless, behavioural interactions have not been observed

between individuals from northern, southern and "offshore" *resident* communities, and differences in mitochondrial DNA and physical appearance suggest the communities are reproductively isolated (Baird and Stacey 1988; Stevens et al. 1989; Hoelzel and Dover 1991; Walters et al. 1992; Ford et al. 1994a; Hoelzel et al. 1998; Matkin et al. 1998). The northern and southern *resident* communities also appears to have distinct behavioural characteristics (Osborne 1986; Hoyt 1990); whether "offshore" Killer Whales exhibit such distinctive behavioural characteristics is unknown, simply due to the relative paucity of work that has been undertaken on that population. Regions identified as high use areas ("core areas") for northern and southern *residents* are separated by about 400 km (two and a half days of travel at 3.5 knots — Bigg 1982).

Distribution and Movements

Killer Whales are cosmopolitan, having been observed in all oceans of the world (Leatherwood and Dahlheim 1978; Dahlheim and Heyning 1998). However, concentrations generally occur in colder regions and in areas of high productivity (Bigg et al. 1987; Heyning and Dahlheim 1988; Guinet and Jouventin 1990). In polar areas the occurrence of Killer Whales is thought to be limited by the presence of pack ice in winter months (Reeves and Mitchell 1988a), thus some north-south movements would have to occur in such areas. A recent sighting by Gill and Thiele (1997) of Killer Whales deep in Antarctic sea ice in winter indicates that not all individuals move away from the poles. Gill and Thiele (1997) suggest that the extreme seasonal differences in the number of observers in polar regions could be partly responsible for the perception that Killer Whales do migrate. In general, no clear evidence of seasonal north-south migrations is available. In the southern hemisphere, based on sightings from whaling vessels, Mikhalev et al. (1981) described seasonal migrations from low-latitude areas in the winter months to higher latitude areas in summer. However, no information was presented on potential seasonal biases in effort, so it is difficult to judge the validity of such conclusions (Perrin 1982).

Within British Columbia, Killer Whales have been documented throughout virtually all salt-water (and some-fresh water) regions, including many long inlets, narrow channels and deep embayments. Both *resident* and *transient* Killer Whales have been recorded year-round in British Columbia. Presence of *resident* Killer Whales seems to be closely tied with peak abundance of various species of salmon, one of their primary prey (Heimlich-Boran 1986; Bigg et al. 1987; Nichol and Shackleton 1996). Several authors have suggested that *residents* are rare in the core study areas of Johnstone Strait and Haro Strait during winter months. However, in both areas one pod (A5

in Johnstone Strait, J1 in Haro Strait) is recorded during most winter months (D. Ellifrit, P. Spong, H. Symonds, personal communications). Broad scale shifts in distribution are apparent, though they are more conclusive for northern *residents* than southern *residents*, since there are two year-round land-based research projects being undertaken in or near the core area for northern *residents* (Morton 1990; P. Spong, H. Symonds, personal communications). There are several seasonal biases in effort which should be taken into account in terms of the seasonal distribution of southern *residents*, and the seasonal distribution of northern *residents* outside of the core area of Johnstone Strait. Inclement weather conditions and low daylight hours during winter months likely decrease the probability of visually detecting Killer Whales when they are present, and little winter work has ever been undertaken. Some evidence is available to suggest that northern *residents* decrease their frequency of vocalizing during winter months (Bain personal communication); this may confound examinations of winter occurrence using this method. Similarly, southern *residents* appear to travel further from shore during winter months (Baird unpublished; D. Ellifrit, personal communication), biasing detection based on shore-based observations. As such, more thorough examinations of seasonal movements (perhaps using satellite telemetry) and winter habitat use are warranted.

Seasonal influxes of Killer Whales into near-shore areas where pinnipeds are abundant have been noted at Marion Island, the Crozet Archipelago, and Punta Norte, Argentina (Condy et al. 1978; Guinet 1992; Hoelzel 1991). Baird and Dill (1995) showed that a strong seasonal peak in occurrence of *transient* Killer Whales in southern British Columbia coincided with the period when harbour seal pups were being weaned. However, only some pods appeared to preferentially use the area during that time, while others were seen regularly year-round (Baird and Dill 1995). Those pods which used the area year-round also tended to travel further from shore, where land-based observers or spotters were less likely to detect them. Because of this seasonal difference in use of near-shore areas, Baird and Dill (1995) and Baird (1995a) suggested that many studies which are shore-based may be biased when examining seasonal presence.

Killer Whales have been documented moving long distances, with some individual *transients* and "offshore" Killer Whales identified both in central California and southeastern Alaska, a 2660 km one-way distance (Goley and Straley 1994; Black et al. 1997). Actual home range sizes are unknown, since virtually no photo-identification work has been done in offshore areas (though see Black et al. 1997), and no animals have been satellite-tagged. Using the northern- and southern-most sightings of particular individuals, combined with the limited knowledge of onshore-offshore movements, the largest docu-

mented range for a *transient* in British Columbia is 140 000 km², while the largest documented range for a *resident* is approximately 90 000 km² (Baird 2000). Both *residents* and *transients* have been documented to move up to 160 km in one 24 hour period, but pods of both types also spend extended periods in small areas.

A comprehensive review of all records available for Killer Whales in the eastern Canadian Arctic and the western North Atlantic was last undertaken in the 1980s (see papers in Sigurjonsson and Leatherwood 1988). Sergeant and Fisher (1957) stated that Killer Whales migrated northwards in the spring along the coasts of Labrador and Newfoundland, though a more comprehensive review by Mitchell and Reeves (1988) concluded that biases in effort precluded the determination of any obvious pattern of distribution or movements. Killer Whales are occasionally recorded in virtually all areas off eastern Canada, including Nova Scotia (Katona et al. 1988), in the Gulf of St. Lawrence (Wenzel and Sears 1988), off Newfoundland and Labrador (Lien et al. 1988), and in Hudson Bay and the Canadian Arctic (Reeves and Mitchell 1988a), with one record from 81°N. Records from these compilations end in the early 1980s, thus another review incorporating more recent records is warranted. Based largely on records collected since the earlier review, it appears that there are only a couple of areas where Killer Whales appear to be somewhat regular in their occurrence. These include the Mingan Islands, Quebec, where R. Sears (Mingan Island Cetacean Study, personal communication) has observed the same small group of whales a number of times since 1984 (see Wenzel and Sears 1988), the western end of the Strait of Belle Isle (R. Sears, personal communication), off Battle Harbour, Labrador (S. Todd, College of the Atlantic, personal communication), and around Pond Inlet, Cumberland Sound, and the Lancaster Sound region, where regular, and possible annual visitation has been noted (Reeves and Mitchell 1988a). In the western Canadian Arctic, some published distribution maps show the presence of Killer Whales (Jefferson et al. 1991; Dahlheim and Heyning 1998; Figure 1) in the Canadian side of the Beaufort Sea. According to two sources (T. Barry, L. Harwood, personal communications), native elders recall sightings of Killer Whales in the area in the 1940s or 1950s, however numerous researchers who have undertaken surveys there in the last thirty years have never seen this species (M. Fraker, L. Harwood, D. Ljungblad, S. Moore, W. J. Richardson, personal communications). Any Killer Whales which do travel into the Canadian Beaufort Sea are likely part of the Bering Sea population (Dahlheim 1997).

Protection

Two factors are important in the legal protection of a species, the system that is in place to prohibit or regulate hunts or other threats, and the system for

monitoring and enforcing regulations. Where information is available, each of these is discussed below.

International

Two international management measures/agencies are relevant to the protection of Killer Whales, CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora in 1973) and the IWC (International Whaling Commission).

All species of cetaceans are listed by CITES under one of two appendices. Appendix I includes species threatened with extinction (and which may be affected by trade), while Appendix II includes species which may become threatened with extinction unless trade is regulated, as well as species which must be subject to regulation in order that trade in threatened species of similar appearance may be controlled (Klinowska 1991). Killer Whales (and all species of cetaceans not listed under Appendix I) are listed under Appendix II for the latter of the above reasons. As such, international trade of Killer Whales or parts thereof by any countries which are Parties to CITES requires export permits from the country of origin. According to Klinowska (1991) the European Community treats all cetaceans as if they were listed in CITES Appendix I — thus trade requires permits from both exporting and importing countries and such trade must not be primarily for commercial purposes. Some other countries (e.g., USA) also have similar domestic rules, requiring both export and import permits for Appendix II species. As of October 1998 there were 144 Parties to CITES, leaving approximately 90 countries world-wide which were not members (CITES Secretariat statistics). This latter group includes Iceland, which has been actively involved in trade (see Limiting Factors below). Listing on CITES Appendix II does not provide protection *per se*, though it does mandate recording of international trade. In recent years, the only international trade of Killer Whales documented through CITES has been in small numbers of live animals between aquaria, a few scientific samples, and small numbers of teeth and carvings. Trade in teeth and carvings have primarily involved the transfer of these items between Greenland (a dependency of Denmark) and Denmark (CITES Secretariat statistics). Although all trade in Appendix II species from a CITES member should be documented, during a recent review of all Killer Whales kept in captivity (Hoyt 1992), E. Hoyt (personal communication) noted that some trade involving CITES countries had not been reported.

Killer Whales are considered “small cetaceans” by the IWC, and there is currently considerable disagreement within the Commission as to whether small cetaceans are covered by the Convention. However, in 1980, in response to a large Russian

take of Killer Whales in the Antarctic in the 1979/80 season, the IWC added a new sentence to Schedule paragraph 9(d), officially including Killer Whales in their moratorium on factory ship whaling (IWC 1981). Other IWC management measures (e.g., the Southern Ocean Sanctuary, moratorium on commercial whaling, etc) do not apply to Killer Whales.

National

Canada: Within Canada, management of Killer Whales has varied considerably over time, and both the federal government and one provincial government (British Columbia) have been involved in management activities. Prior to 1970 no laws were in place to control or regulate captures or other interactions. Hoyt (1992) notes that news reports of deaths during captures and the out-of-country destinations of captured Killer Whales in the 1960s prompted wide-spread public pressure for the implementation of protective legislation. Such legislation was first introduced in 1970. Prior to 1982, Killer Whales were considered “wildlife” by the British Columbia provincial government’s Wildlife Branch, and possession permits could be issued for holding these animals in captivity. In 1982 the provincial Wildlife Branch re-wrote the “Wildlife Act”, and deleted Killer Whales from the list of wildlife, in response to a federal move to include all cetaceans under the “Cetacean Protection Regulations” (under the Fisheries Act of Canada of 1867). These regulations prohibited “hunting” without a license. “Hunting” was defined as “to chase, shoot at, harpoon, take, kill, attempt to take or kill, or to harass cetaceans in any manner”. No scheme, however, was in place to enforce such regulations, and aboriginal hunting could be undertaken without a license. In 1993, the federal government consolidated various marine mammal regulations, including the Cetacean Protection Regulations, under the new “Marine Mammal Regulations”. These regulations stated that “no person should disturb a marine mammal except when under... the authorities of these regulations”, with “marine mammal” defined as all species listed under a particular appendix. However, many species of cetaceans, including Killer Whales, were not listed under that appendix, and thus no legal protection appears to have been in place. The definition of “marine mammal” was revoked in 1994, thus extending coverage to all species of marine mammals. Currently, hunting of Killer Whales can occur if a “Fishing License” is obtained (except for Aboriginals who can hunt without a license), but fees for such licenses are low (\$5). However, no such licenses have been issued, and issuance is at the discretion of the federal Minister of Fisheries and Oceans. It is unlikely any would be issued in areas such as British Columbia, due to widespread public interest in these animals.

In terms of minimizing negative interactions

between boats and Killer Whales, “whale watching guidelines” have been produced and disseminated by the Department of Fisheries and Oceans. There are also several ongoing efforts of self-regulation by the commercial whale watching industry in British Columbia, involving the production of guidelines and codes of conduct (Baird et al. 1998b). Among commercial operations in certain specific areas, the levels of awareness of and adherence to these guidelines is fairly high, though awareness and adherence by general members of the public (which make up the majority of boats with whales in some areas – see Figure 5) is currently unknown. As with the Cetacean Protection Regulations, virtually no official monitoring or enforcement activities take place, and enforcement itself is complicated by the difficulty in defining and measuring “harassment” in the field (see Limiting Factors, below). N. Bhaloo (DFO Conservation and Protection, Enforcement Unit, personal communication) notes that no violations of the Marine Mammal Regulations involving Killer Whales have been documented between 1993 and 1997, although there is one charge of harassment, involving a sports fishing operation outside of either of the two core areas for *residents*, pending

from 1998 (E. Lochbaum, DFO, personal communication).

The 1997 Oceans Act provides for the establishment of marine protected areas (MPAs) in federal waters. One of the specific justifications listed for establishing MPAs is to conserve and protect marine mammals and their habitats. However, as with other federal legislation regarding marine mammals, establishment of marine protected areas and exclusion of activities which might jeopardize Killer Whales or other marine mammals are up to the discretion of the Minister of Fisheries and Oceans, rather than mandated. Regardless, there are general concerns about the efficacy of using MPAs to “protect” cetaceans (see below, as well as Phillips 1996; Whitehead et al. 2000), due primarily to the large range of most species and the lack of boundaries in the marine environment. Whitehead et al. (2000) note that most marine protected areas have provided little or no change in the level of threats faced by cetaceans in an area.

One example of an MPA specifically created to “protect” Killer Whales is the Robson Bight/Michael Bigg Ecological Reserve, a provincial designation in a core area for northern *residents*. This designation provides some protection to the shoreline habitat and limits human access by land. Its main relevance to Killer Whales is the protection of the terrestrial portion of several “rubbing beaches” which are regularly used by northern *residents*. However, its validity as a “whale sanctuary” has been questioned. Duffus and Dearden (1992) state that this designation “holds a fairly limited potential to protect a marine area”, since it is the federal government that has jurisdiction over marine shipping and marine fisheries, and this is a provincial designation. They also note that the “boundary is highly permeable, and buffers of outside impacts are almost non-existent” (Duffus and Dearden 1992). They warn against the “fallacy of tokenism — that is, giving the public the appearance of protecting an important whale habitat, when neither the importance of the site to the whales, nor the veracity of the protection is established — creat[ing] a political “success” that may mask an ecological failure” (Duffus and Dearden 1992). Other than this effort by the British Columbia provincial government, no other province or territory within Canada has legislated protection for this species.

Other Countries: Considering that Killer Whales regularly move between Canada and other countries (the U.S. on both coasts and almost certainly Greenland, see Heide-Jorgensen 1988, 1993; Mitchell and Reeves 1988), protection measures in these countries are directly relevant to the conservation of Killer Whales in Canada. In the United States, all cetaceans are protected through the Marine Mammal Protection Act of 1972, as well as through the Packwood-Magnuson Amendment of the Fisheries and Conservation Act and the Pelly Amendment of

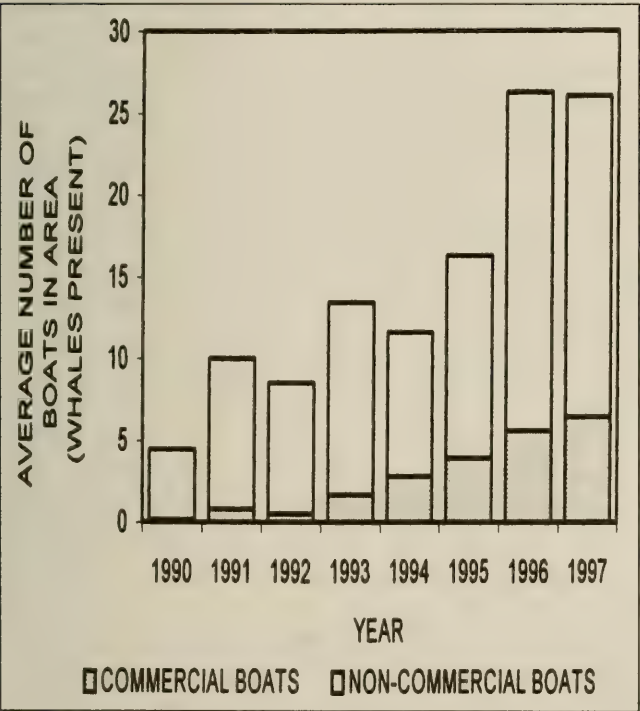


FIGURE 5. Trend in the average number of boats (both commercial whale watching operations and total boats) with southern *resident* Killer Whales as they pass the Lime Kiln Lighthouse on San Juan Island, Washington state, from 1990 through 1997. Data were collected from mid-May through mid-August each year, seven days per week, from 0900 till 1700 h. No such increasing trend was apparent when no whales were present. Data from R. Otis (see Baird et al. 1998b).

the Fisherman's Protective Act. These regulations allow for observers on fisheries that have a high probability of killing marine mammals, and also provide for limited monitoring and enforcement activities regarding boat/whale interactions. There are no management measures in Greenland that provide protection for Killer Whales, and kills in that area (see Limiting Factors, below) could affect Canadian populations.

Population Sizes and Trends

No world-wide population estimates are available. Regional population estimates, where available, have been derived through photo-identification surveys and/or line-transect surveys. Line-transect surveys have generally been used in areas where more intensive photo-identification studies are impractical (e.g., the Southern Ocean), but are also accompanied by large confidence limits (see e.g., Matkin and Saulitis 1994). Furthermore line-transect surveys do not allow for discrimination of individuals from sympatric populations.

In British Columbia, four separate populations must be considered, *transients*, "northern" and "southern" *residents*, and "offshore" Killer Whales (which should probably be considered "offshore" *residents*, see discussion above). The most detailed information is available for northern and southern *residents*, as all of the southern *resident* pods and many of the northern *resident* pods are censused each year. As all individuals are recognizable, the census provides an actual count of the number of individuals in the population. As of 1998, the southern *resident* population numbered 89 individuals (van Ginneken and Ellifrit 1998). While the population has grown since the cessation of the live-capture fishery in 1973, the current population is smaller than the population near the start of that fishery (Figure 6), and has declined for the last three years (1996–1998). Such a decline is not unprecedented (Olesiuk et al. 1990; Figure 6); since the cessation of the live-capture fishery the population showed a similar decline from 1980 through 1984. As discussed under Limiting Factors (below), this earlier decline was likely due in part to the removal of animals in the live-capture fishery (Olesiuk et al. 1990). The most recent decline appears to have resulted from an increased death rate. Using data presented by van Ginneken and Ellifrit (1998), the average per capita death rate between the years 1995 to 1998 (mean of 0.052) is significantly higher (Mann-Whitney U-test, $p = 0.0084$) than the average for the preceding 19 years (mean of 0.021 from 1976 through 1994). The per capita birth rate for this same period (mean of 0.034) is similar to the average for the previous 19 years (mean of 0.038). In the period from 1995 to 1998, age-specific mortality rates for mature females between 35 and 65 years of age are four to five times

higher than reported by Olesiuk et al. (1990; see Table 2). It is unclear however whether this current population decline may be due to demographic stochasticity, or even perhaps delayed effects of the removal of animals in the live-capture fishery, and a study modeling the probability of such effects occurring by chance or due to selective removals is warranted.

As of 1993 the number of northern *residents* thought to occupy British Columbia waters (if only seasonally) numbered approximately 200 individuals (Ford et al. 1994a). More recent surveys have been undertaken, but the Department of Fisheries and Oceans, Pacific Region, which undertakes these surveys, has not released current data. This "population" has been growing at a relatively stable rate since the 1960s (Olesiuk et al. 1990; Ford et al. 1994a). Because of the associations and shared mtDNA haplotypes with *residents* in Alaska, the effective population size for northern *residents* should probably be considered larger than the absolute number recorded within British Columbia waters, and the overall trend in the larger population is unknown (since less complete information is available for Alaskan *residents*). Population estimates for several regions of Alaska are available and are summarized by Matkin and Saulitis (1994). Taking into account only those whales documented in British Columbia, there was no evidence of density-dependent effects as of the late 1980s (Meyers 1990), but data collected since then have not yet been examined. Brault and Caswell (1993) examined pod-specific demography of *residents*, and concluded that most of the variance in individual pod growth rates was due to variance in adult reproductive output, rather than effects of pod size or structure.

Population size is not known for "offshore" Killer Whales. The first "offshore" Killer Whales groups were encountered in the mid-1980s, and about 200 "offshore" Killer Whales had been documented as of 1993 (Ford et al. 1994a). These whales have been identified over a relatively short period of time, thus while natural mortality should only have accounted for a few deaths, new individuals are being regularly documented (Walters et al. 1992; Ford et al. 1994a). Of 56 "offshore"-type whales documented off California, 23 were direct matches with "offshore" Killer Whales recorded off Oregon, Washington, British Columbia and southeast Alaska (Black et al. 1997). No trend information is available for this population.

For *transient* Killer Whales, the total population size is unknown but probably numbers in the low hundreds. Seventy-nine *transients* had been photo-identified in British Columbia and Washington up to 1986 (Bigg et al. 1987), and a further 90 or more have been documented in the 10 years since (Ford et al. 1994a). Considering their wide-ranging move-

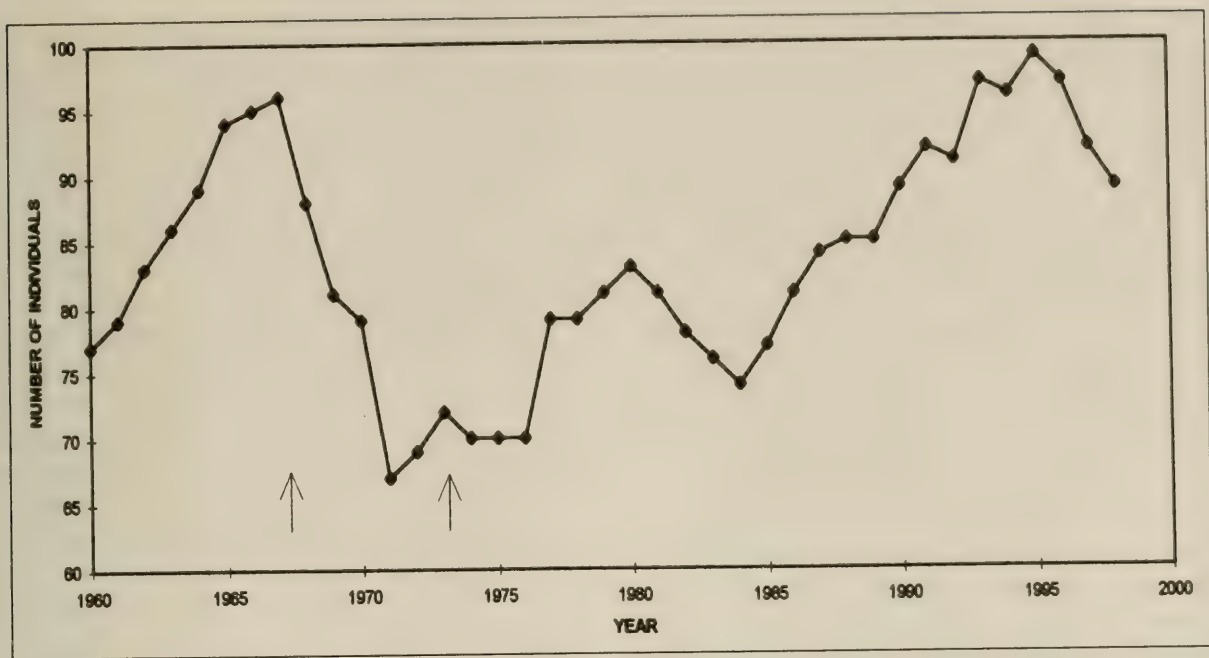


FIGURE 6. Population numbers and trends for southern *resident* Killer Whales. Data in this graph are from van Ginneken and Ellifrit (1998) and Olesiuk et al. (1990). Where differences exist between the two sources I have followed van Ginneken and Ellifrit (1998). The left arrow marks the beginning of large catches of whales from this population in the live capture fishery (small numbers had been taken prior to that point), while the right arrow marks the cessation of that fishery. Data from 1975 on are counts of animals using photo-identification; prior to that point numbers given are projections from a matrix model (Olesiuk et al. 1990). While there has been an increase since the end of live-captures, readers should compare the unsteady growth of this population since 1973, with the relatively steady continual increase of the northern *resident* population (Olesiuk et al. 1990; Figure 26).

ments, known associations, and shared genetic haplotypes, *transients* from bordering areas should be considered part of the same population which uses B.C. waters (Black et al. 1997). Of 79 *transients* documented in southeast Alaska, 69 have been observed in British Columbia (Dahlheim et al. 1997; Ford and Ellis 1999). One hundred and five *transients* have been documented off California, and at least 10 of those have been documented in British Columbia, Washington, or further north in Alaska (Black et al. 1997). New individuals are occasionally being recorded in some areas (e.g., van Ginneken et al. 1998). Because of the long-resighting interval for some *transients*, it is not possible to determine

deaths in the same way as for *residents*, thus some of the whales already documented are probably no longer living. The use of mark-recapture models for estimating *transient* population size is not appropriate, as the probability of encountering *transients* in any particular area differs between groups (see Baird and Dill 1995, and differences between regional catalogues, e.g., Black et al. 1997; Palm 1997; van Ginneken et al. 1998). Population trend information is unavailable.

No population estimates are available for the Canadian Arctic or Atlantic waters, though compilations of records have been presented by Lien et al. (1988), Mitchell and Reeves (1988), Reeves and

TABLE 2. Comparison of age-specific mortality rates for all mature female southern *residents* from 1995–1998 (data from van Ginneken and Ellifrit 1998) with values presented by Olseiuk et al. (1990).

Age group	Olesiuk et al. 1990 <i>residents</i>	1995–1998 southern <i>residents</i>
15.5–24.5	0.0000	0.0
25.5–34.5	0.0036	0.0
35.5–44.5	0.0109	0.05
45.5–54.5	0.0250	0.125
55.5–64.5	0.0328	0.14
>65	0.069	0.05

Note: While sample sizes are small, and this is a post-hoc comparison looking only at a four-year period where a decline in the population has been noted, mortality rates for mature females between 35 and 65 years of age are four to five times higher than the rates calculated by Olesiuk et al. (1990).

Mitchell (1988a) and Wenzel and Sears (1988). Some anecdotal evidence suggests that the number of whales which utilize the St. Lawrence has declined in the last 60 years; Vladykov (1944) reports that large numbers of Killer Whales (including groups up to 40 individuals) were found in the area in spring and fall, feeding on belugas. It is clear that numbers which utilize the area today are much smaller (Mitchell and Reeves 1988; Wenzel and Sears 1988). The largest group reported off eastern and Arctic Canada in the last 20 years appears to be of 22 individuals (Finley 1990). Mitchell and Reeves (1988) note that Killer Whales appear to be "uncommon in the western North Atlantic relative to other medium-sized and large cetaceans, and that they may be numerically few" (this view is supported by data presented by Lien et al. 1988). As noted above, a review of western North Atlantic records subsequent to those mentioned above is warranted. Regional estimates for some portions of the eastern North Atlantic suggest relatively large populations (Anonymous 1993). Off West Greenland, considerable survey efforts have been undertaken since 1984, yet few Killer Whales have been recorded, suggesting that Killer Whales are not abundant in that area (Anonymous 1993).

Habitat

Killer Whales do not appear to be as limited by such habitat considerations as depth, water temperature, or salinity, as do some other cetaceans. Killer Whales are found in all oceans, in water ranging in temperature from below zero degrees Celsius (among ice floes) to warm tropical waters. They have been recorded in depths from as shallow as a few meters, to open ocean depths. Killer Whales will also occasionally spend considerable time in brackish water and will even enter rivers (e.g., Scheffer and Slipp 1948), including ascending into the lower reaches of the Fraser River in British Columbia. Resident Killer Whales around northern Vancouver Island have been documented using shallow intertidal and subtidal pebble beaches as rubbing sites (Hoyt 1990).

Habitat use by *residents* and *transients* does differ (Heimlich-Boran 1988; Morton 1990; Felleman et al. 1991; Baird et al. 1992; Ford et al. 1994a; Baird and Dill 1995). Both *residents* and *transients* frequent a wide range of water depths, but *residents* tend to spend more time in deeper water. *Residents* will occasionally move into water less than five meters deep, but some *transient* pods spend considerable time in even shallower depths, often foraging in intertidal areas at high tides. There appears to be considerable variability in habitat use among *transient* pods, with some spending significantly greater time foraging in very near-shore areas than others (Baird and Dill 1995). Patterns of habitat use of *resi-*

dent Killer Whales in Washington state and southern British Columbia were examined by Heimlich-Boran (1988) and Hoelzel (1993). Both studied the same population, but over different time periods; and results presented from the two studies differ somewhat. Heimlich-Boran (1988) noted that *residents* fed more in specific areas with high relief bathymetry along the major routes for salmon migration. Hoelzel (1993) found no correlation between behaviour, bottom topography or specific areas. The reasons for these discrepancies are unclear; habitat use may have shifted somewhat between the two study periods, or differences in methodology may be responsible. For both *residents* and *transients*, given the matrifocal nature of groups, movement patterns and habitat use are likely strongly influenced by learning within the matrilineal unit.

General Biology

Life History/Reproduction

The most detailed information on life history of Killer Whales world-wide is available for northern and southern *residents*. Life history characteristics determined by Olesiuk et al (1990) and summarized below were calculated using data from both northern and southern *residents* (and all references to *residents* in this section apply to both populations except where specified). As many of the characteristics may vary between populations, application of these values to other populations, including "offshore" Killer Whales or *transients*, should be done with caution. Some information, such as gestation period, has best been established with captive animals.

Gestation periods has been reported variously to be between 12–17 months. Using hormone levels of captive animals, gestation period has been measured at 517 days (17 months, SD = 20 days; Walker et al. 1988; Duffield et al. 1995). Duffield et al. (1995) note that successful pregnancies with viable calves occurred from 15–18 months (468–539 days). Length at birth of *residents* (based on the smallest and largest newborn animals documented stranded) ranges from 218 to 257 cm (Olesiuk et al. 1990). The largest fetus recorded world-wide was 270 cm in length (Nishiwaki and Handa 1958). Calving occurs year-round, but there appears to be a peak in births between fall and spring (Olesiuk et al. 1990). Precise age at weaning is not known, but Killer Whale calves begin taking solid food at a very young age. Heyning (1988) noted solid food in the stomach of a 2.6 m long animal from California. No milk was visible in the stomach of that animal, but contents were not tested for the presence of milk lactose. Using the ages at which southern *residents* begin spending more time away from their mother, as well as when they are observed taking fish, Haenel (1986) estimated weaning to occur at between 1.0–1.5 to 2 years of age.

Age at sexual maturity for females can be reported in a variety of ways, including age of first ovulation, age at first pregnancy, and age at first parturition. Olesiuk et al. (1990) defined age at sexual maturity for females as the age at which they first give birth to a viable offspring, and noted that it varies between 12 and 16 years (mean = 14.9 years). Onset of sexual maturity for males, defined as when the dorsal fin shape changes sufficiently enough to distinguish males from females, ranged between 10–17.5 years (mean = 15 years) (Olesiuk et al. 1990). Dorsal fin growth for males continues for at least six years after onset of sexual maturity, and Olesiuk et al. (1990) suggest that physical maturity is reached at the end of that period. These criteria need to be evaluated using hormone levels of captive animals. Calving interval, defined as the interval between births of viable calves, ranges from 2 to 12 years, with a mean of about 5 years (Olesiuk et al. 1990). Calving interval increases slightly with age, but is extremely variable (Olesiuk et al. 1990). Fecundity rate (defined as the proportion of mature females which gave birth to viable calves each year) declines linearly with age (Olesiuk et al. 1990). Olesiuk et al. (1990) provide evidence of reproductive senescence in older females, and note that the mean age of onset of post-reproduction is about 40 years, although one female has given birth at 51 years of age.

Mortality rates vary with age. Neonate mortality (birth to six months of age) is high. Using survival rates of calves first encountered during winter, and the presence of stranded animals, Olesiuk et al. (1990) estimated neonatal mortality of *residents* at 37% and 50%, respectively. Bain (1990) independently estimated neonatal mortality in northern *residents* at 42%, based on the distribution of calving intervals. Because of the high mortality rate during the first six months of life, longevity has usually been reported as the average lifespan of an animal which reaches six months of age. Average longevity has been estimated for male *residents* to be 29.2 years (maximum estimated at 50–60 years), and for females to be 50.2 years (maximum estimated at 80–90 years) (Olesiuk et al. 1990). At birth, average life expectancy is about 29 years for females and 17 years for males (Olesiuk et al. 1990).

Feeding Habits

Information on diet composition is relevant to status assessment both in terms of potential limiting factors, as well as in population delineation. In general, Killer Whales world-wide are apex predators, with a wide range of prey reported, including squid, octopus, bony and cartilaginous fish, sea turtles, sea birds, sea and river otters, dugongs, pinnipeds, other cetaceans, and occasionally terrestrial mammals such as deer, moose and pigs (Heyning and Dahlheim 1988; Guinet 1992; Jefferson et al. 1991). However,

individual populations of Killer Whales appear to specialize on particular types of prey, rather than exhibit opportunistic predation (Felleman et al. 1991; Jefferson et al. 1991; Baird et al. 1992). In some areas, Killer Whales regularly steal fish from commercial fisheries (e.g., Leatherwood et al. 1990; Sivasubramaniam 1965; Yano and Dahlheim 1994, 1995), or scavenge discards thrown overboard (e.g., Couperus 1994).

Both northern and southern *residents* appear to feed primarily on fish (Ford et al. 1998). More information is available for northern *residents* (126 predation events) than for southern *residents* (35 predation events), and most records of predation are from during the summer months (Ford et al. 1998). Based on collection and identification of scales from fish captured, Ford et al. (1998) note that 96% of the fish kills observed were salmonids, and of these, 65% were of Chinook (*Oncorhynchus tshawytscha*), the largest species occurring in that area. Stomach contents from eight *residents* also indicate this preference for salmon (7 of 8 individuals) and for Chinook (at least 4 individuals), though a variety of other species, including Pacific Halibut (*Hippocampus stenolepis*), Lingcod (*Ophiodon elongatus*) and a variety of other bottom fish were noted from one or two animals, and from occasional observations of predation (Ford et al. 1998). Ford et al. (1998) note that there are several potential biases that could affect diet composition in this type of study. It is possible that prey caught at great depths may be consumed prior to a whale returning to the surface. The limited information available on the depth distribution of salmon in British Columbia and Washington suggest that most species spend the majority of their time in the upper levels of the water column (i.e., less than 30 m — Felleman 1986; Quinn and terHart 1987; Quinn et al. 1989; Ruggerone et al. 1990; Olson and Quinn 1993), though Chinook are the deepest of the species captured. Thus most salmon captured likely have a relatively high probability of being observed, compared to prey which usually inhabit deeper portions of the water column. Southern *resident* Killer Whales regularly dive to depths greater than 100 m (Baird et al. 1998a), and may take a minute or more to return to the surface. While details on handling time of salmon have not been reported, it seems likely that similar-sized fish caught at such depths may be consumed prior to the whale's surfacing. Information on handling time for various species and sizes of fish would be of value for assessing this possibility. Also, there may be a bias towards detecting captures of large prey. Small prey are likely swallowed whole, while large prey may be broken up prior to consumption or shared between individuals, thus increasing the chance that scales may be recovered at the surface. Little information is available on diet of "offshore" Killer

Whales, though they have not been observed feeding on marine mammals (Ford et al. 1994b).

I believe that diet information from most observational studies of *transients* is probably less biased, since marine mammal prey tend to be fairly large and often come to the surface to breathe during attacks, where they are easily seen (Baird and Dill 1996; Ford et al. 1998). Even when live prey are not observed at the surface, prey species can often be inferred, based on location (e.g., a Harbour Seal haulout), and the presence of large quantities of blood or blubber in the water. However, methods in many studies focused on acoustic recordings have required positioning of a research vessel relatively far away (e.g., 100s of meters) from whales under observation, and it may therefore not be possible to compare kill rates from one study to another (Baird 2000). In one observational study, calculated food intake rates were more than sufficient to meet the animals' predicted energetic needs, thus the vast majority of prey actually captured were probably documented (Baird and Dill 1996). Harbour Seals seem to be the preferred prey for *transients*, being both very abundant in many areas of British Columbia, as well as relatively easy to capture (Baird and Dill 1996; Ford et al. 1998). Virtually all other common species of marine mammals whose range overlaps with that of *transients* have also been documented as their prey, as have occasional sea birds and even terrestrial mammals (Pike and MacAskie 1969; Bigg et al. 1987; Jefferson et al. 1991; Stacey et al. 1990; Baird and Dill 1996; Ford et al. 1998).

Killer Whales in the Canadian Arctic and Atlantic have primarily been documented feeding on other marine mammals (Whitehead and Glass 1985; Mitchell and Reeves 1988), though some evidence of Killer Whales scavenging fish from around longlining vessels is also available (Sergeant and Fisher 1957).

Social Organization

Globally, Killer Whales have been observed traveling alone and in groups of up to several hundred individuals (Perrin 1982). However, larger groups appear to be temporary associations of smaller, more stable groups. In all areas where long-term studies have been carried out, evidence suggests stable multi-year associations between individuals with limited dispersal from maternal groups (Lopez and Lopez 1985; Bigg et al. 1990; Guinet 1991a; Simila and Ugarte 1993; Baird and Dill 1996; Baird and Whitehead 2000). Such evidence is most conclusive for Killer Whales in British Columbia and Washington (both *transients* and northern and southern *residents*), where there are extensive data on variability in group size, structure and stability. Differences in these characteristics do occur between the sympatric *residents* and *transients*. Little is

known about the social organization of "offshore" Killer Whales.

Bigg et al. (1990) studied the social organization of northern and southern *residents*, and noted the average pod size in the two populations combined was about 12 individuals (range of 3–59 individuals). No dispersal from *resident* pods has been documented. *Resident* pods are thought to form by the gradual splitting of a single pod into two (Ford 1990). Ford's (1984; 1990) research on Killer Whale acoustics demonstrated the existence of stable pod-specific dialects, and showed that some pods shared a number of calls. He suggested that these reflected common ancestry. Ford (1990) defined acoustic clans, comprised of pods which share one or more calls, and identified four acoustic clans from the British Columbia coast, three within the northern *resident* community, and one in the southern *resident* community.

For *transient* Killer Whales, average pod size reported by Baird and Dill (1996) was of about two individuals, with a range in pod size from one to four individuals. Those pods which consist of only a single individual (ie., individuals who do not associate with others for more than 50% of their time) appear to be of two types, either lone adult males which tend to spend much of their time alone (and only occasionally associates with other groups; Baird 1994), or adult females which always associate with other groups, although none in a stable manner (Baird and Whitehead 2000). *Transient* pods are fairly stable, with some associations between individuals documented lasting 15 years or more (Baird and Whitehead 2000). However, dispersal from *transient* pods has been recorded on two occasions (Bigg et al. 1987; Baird and Dill 1996), and extensive indirect evidence of dispersal exists (Baird 2000). *Transient* pods often associate with one another, and no evidence of *transient* communities, as noted for *residents*, has been found. Associations between *transient* pods do not appear to be completely random however; they depend in part on pod size and the age and sex of all pod members (Baird 2000), and in part on the foraging tactics exhibited by the pod, which appear to be pod-specific (Baird and Dill 1995).

Limiting Factors

Natural Mortality

Potential sources of natural mortality fall into several categories: predation, parasitism, disease, biotoxins, accidental beaching, entrapment, and starvation. No predators of Killer Whales have been recorded, but young or sick whales are potentially at risk from attacks by large sharks in some areas, and attacks by other Killer Whales may also pose a risk (see above). The relatively high incidence of scarring on animals also suggests that intraspecific aggression occurs (see Visser 1998).

A variety of endoparasites have been recorded from Killer Whales, including trematodes, cestodes, and nematodes (see review in Heyning and Dahlheim 1988). Transmission of such parasites is primarily through ingestion of infected food items, but the role and extent of such parasites in causing natural mortality is unknown. External parasites have not been documented in British Columbia Killer Whales, but Killer Whales elsewhere have been seen with barnacles on the rostrum and trailing edge of flukes, and with a species of cyamid ectoparasite. The current understanding of the diseases and disease processes (e.g., Ridgway 1979) affecting Killer Whales is relatively advanced, as a result of the study of animals in aquaria (J. McBain, Sea World San Diego, personal communication). Relatively little of this research has been published however. Mortality due to biotoxins has not been reported for Killer Whales, though a number of large-scale mortality events in other cetaceans have been linked to this source (e.g., Geraci et al. 1989). Large-scale mortality events due to viral infections have been recorded in several populations of marine mammals in recent years (Osterhaus and Veder 1988; Duignan 1995), and while the occurrence of such die-offs is unpredictable, given their magnitude and apparently increasing frequency of occurrence, they should be taken into account in conservation planning and population viability analysis (Young 1994; Simmonds and Mayer 1997).

Accidental beaching and entrapments of Killer Whales are an occasional source of natural mortality. Several cases of beaching of live animals have been reported in British Columbia and off eastern Canada, both with large groups (Carl 1946; Dearden 1958; Emery 1960) and lone individuals (Hoyt 1990). There is one recent unpublished record of two adult individuals which live stranded and died during a storm on 28 January 1998, near Terranceville, Fortune Bay, Newfoundland (R. Hudson, personal communication). Mass strandings have also been reported from Alaskan waters (Hanson and Spraker 1996). The cause(s) of large group strandings are usually unclear (though Dearden 1958 reports animals being forced ashore by ice), but it seems more likely to occur for "off-shore" whales traveling on a rare occasion in inshore waters, than it does for inshore groups. Hoyt (1990) noted one *transient* individual apparently accidentally stranded while chasing porpoise in shallow water. Ice entrapments have been reported in the Canadian Arctic (Reeves and Mitchell 1988a), off Newfoundland (Lien et al. 1988) and in the Antarctic (Taylor 1957). Several cases of animals becoming entrapped in tidal lakes or inlets with narrow, shallow openings have also been noted (Emery 1960; Mitchell and Reeves 1988; Bain

1995). In many cases such entrapment has led to mortality of all or part of a group. Considering the small size of inshore populations of Killer Whales, such periodic events could seriously affect populations. Temporary "entrapment" in narrow inlets has been documented for southern *resident* Killer Whales twice in recent years (Shore 1995, 1998). In the most recent case, occurring in southern Puget Sound in 1997, the whales' reluctance to move under a bridge across the mouth of the inlet was suggested as a possible factor preventing their leaving the enclosed area (Shore 1998). Two of the 19 whales which were in the inlet died at some point in the six months after they left the inlet, though it is unknown whether the "entrapment" was a contributing factor to this mortality (Anonymous 1998).

Anthropogenic Influences

Potentially negative interactions with humans fall under two broad categories. Some impacts may have acute (immediate) effects on individuals or a population, such as directed takes (whaling, culling), live-capture fisheries, entanglement in fishing gear, collisions with vessels, or exposure to acute pollutants (e.g., oil spills). Immunotoxic effects due to accumulation of persistent toxic chemicals may also have an acute impact by increasing susceptibility to diseases, thus causing an increase in mortality. Besides these acute impacts, there are a number of less tangible, longer-term potentially negative human influences, including a reduction in reproductive rates due to accumulation of persistent toxic chemicals, reduced prey availability due to human activities, and disturbance or displacement by vessel traffic or other sources of underwater sounds (Table 3). While each of these is treated independently below, it should also be taken into account that cumulative impacts of all of these factors could be important (or in the case of longer-term stressors, synergistic interactions between impacts could occur; Whitehead et al. 2000).

Killer Whales have been hunted for oil and meat (for human or animal consumption, fertilizer or bait) in many areas (e.g., Reeves and Mitchell 1988b; Oien 1988; Berzin and Vladimirov 1983; Miyazaki 1983; Anonymous 1992; Kishiro and Kasuya 1993; Price 1985; Bloch and Lockyer 1988; Barnes 1991; Yu 1995, though the largest fisheries were discontinued in the early 1980s (Norway and Russia) or early 1990s (Japan). Small numbers are probably still taken elsewhere however. Information on catches is currently reported by many countries that are members of the International Whaling Commission through their Annual Progress Reports, though not all countries submit Annual Progress Reports, and some countries may not include Killer Whales in their lists of catches, as they are considered "small cetaceans" and are thus not covered under the auspices of the IWC. Small numbers of animals may be

TABLE 3. A summary of causes of mortality or disturbance to Killer Whales and their potential role in population limitation. Those sections which are bold are considered to be the most serious threats or limiting factors for Killer Whale populations in Canada.

Threat	Known or thought to cause population decline	Potential to cause substantial population decline	Trend in threat
NATURAL			
Predation	No	No	NA
Die-offs	No (but yes with marine mammals elsewhere)	Yes	Unknown
Mass stranding or entrapment in ice or narrow inlets	Yes	Yes	Steady?
ANTHROPOGENIC			
Culling/direct killing	Yes	Unlikely on west coast, possible in Arctic Canada	Decreasing on west coast, unknown in eastern and Arctic
Incidental mortality	No	No	Steady?
Live capture	Yes	No	Decreasing
Vessel harassment	No	No (but possible contributing)	Increasing
Vessel collision	No	No	Increasing
Acoustic deterrents from aquaculture operations	No	Unlikely	Steady but potential to increase
Immunotoxicity	No (but yes with marine mammals elsewhere)	Yes	Steady or increasing?
Oil spills	No (but yes with other populations)	Yes	Increasing?
Reduction in prey base	No (but yes with marine mammals elsewhere)	Yes	Decreasing for mammal-eating Killer Whales, unknown for fish-eating

taken by non-member countries, and such catches would probably be largely unreported. In Canadian Arctic waters, Killer Whales are only taken very occasionally by native people; Reeves and Mitchell (1988a) noted that there was no tradition of hunting of Killer Whales in this area. Fourteen Killer Whales were killed by native hunters in the Canadian Arctic in 1977, but these were individuals that had been trapped in a tidal lake (Mitchell 1979). Small numbers were taken commercially off of Newfoundland and Nova Scotia in the 1940s through 1960s (Sergeant and Fisher 1957; Mitchell and Reeves 1988), and it is possible that more animals were taken but not reported in an early fishery for pilot whales (Sergeant 1962; Mitchell and Reeves 1988). Catches in the 1960s and 1970s off Norway were both age- and sex-biased, and impacts on the current population may still be apparent (Vongraven and Bisther 1995).

Culling (intentional shooting) of animals, because of their perceived (or documented) threat to fisheries, has also occurred in British Columbia (Carl

1946; Olesiuk et al. 1990), off eastern Canada (Lien et al. 1988), and elsewhere (e.g., Heide-Jorgensen 1988). In British Columbia this included the Canadian Air Force using Killer Whales as practice targets (Carl 1946), as well as opportunistic shooting by fishermen and the federal fisheries department. That such culling may have had an impact on populations earlier in this century is apparent in the population growth curves shown by Olesiuk et al. (1990; see also Figure 6), since both the northern and southern *resident* populations were growing (presumably recovering) prior to the initiation of the live-capture fishery. As such, it is possible that the populations today are still recovering. Elsewhere, as in Prince William Sound, Alaska, direct killing by fishermen in recent years in response to losses of fish may still be having significant effects on the local population (Dahlheim and Matkin 1994). Lien et al. (1988) note that the shooting of Killer Whales which congregated around whaling ships to feed on captured baleen whales may have significantly decreased the population in that area (though whaling ceased there in

1972). Kills in Greenland (Heide-Jorgensen 1988) may be from populations which share their range with Canada (Heide-Jorgensen 1993), and whether the ongoing occurrence of such kills is currently having an impact on populations off eastern and Arctic Canada should be investigated. Killer Whales in British Columbia are not reported to regularly take fish off fishing gear (G. Ellis, personal communication), as has been reported elsewhere (e.g., Yano and Dahlheim 1995), thus it seems unlikely that illegal shooting because of perceived threats to fisheries is currently occurring to any great degree. One fatal shooting of an adult female northern *resident* was documented in 1983 (which also appeared to result in the death of her calf), and at least one other northern *resident* has a bullet hole in the dorsal fin (Ford et al. 1994). Because of the extremely low potential growth rate of Killer Whale populations, even occasional shooting could limit population growth, and some monitoring of such activities is warranted. How such monitoring would be undertaken is difficult to envision.

Incidental mortality in fisheries through accidental entanglement in fishing gear appears to be rare for this species. A few gear entanglements have been reported in British Columbia, though not all have resulted in death of the entangled animals (Pike and MacAskie 1969; Jamieson and Heritage 1988; Ford et al. 1994b; Guenther et al. 1995*; Baird et al. in press). Entanglements have also been reported from other areas where individuals from the British Columbia population range (e.g., Alaska — Barlow et al. 1994; California — Heyning et al. 1994). Off the eastern coast of North America, no reports of incidental mortality in Canadian waters appear to have been published (Read 1994), though there is one record of a Killer Whale entangling in a ground-fish gillnet (though it did not die) in the U.S. waters of the Gulf of Maine (Waring et al. 1997), and one record of a Killer Whale entangling (but released alive) in a swordfish longline in international waters off of Newfoundland (A. Williams, NMFS, personal communication). As with direct killing, some efforts to estimate the numbers of animals which are killed through incidental mortality are warranted. While questionnaire surveys of fishermen are known to be extremely biased (Lien et al. 1994), reporting of such accidental events might be more likely than reporting of deliberate activities like shooting.

Live-capture fisheries for public display in oceanaria have been focused in two areas, British Columbia/Washington and off Iceland (Asper and Cornell 1977; Bigg and Wolman 1975; Hoyt 1992). The last permit for captures in British Columbia was issued in 1982, although no animals were taken; the last animal taken from British Columbia was in 1977, and it is unlikely any further captures would be allowed, due to widespread public opposition

(Hoyt 1990). Of 63 *residents* estimated to be removed from British Columbia/WA, 48 were thought to originate from the southern *resident* community (Olesiuk et al. 1990), which currently numbers only 89 animals (van Ginneken and Ellifrit 1998). These captures substantially reduced the southern *resident* population and it took approximately 20 years to return to levels similar to prior to the fishery (Figure 6). Besides a reduction in numbers, the live-captures also resulted in a skewed age- and sex-composition of the population (Olesiuk et al. 1990), due to selective cropping. Olesiuk et al. (1990) discuss a number of factors which may have resulted in the slow recovery of the southern *resident* population between 1970 and 1985, including the possibility that the selective cropping of males (23 of 35 known-sex individuals were males) may have reduced the number of mature males to below a critical number for optimal productivity (Olesiuk et al. 1990).

In recent years, whale watching focusing on Killer Whales has become particularly prominent in Washington state and British Columbia, and vessel activity of all types (e.g., sports fishing, whale watching, ferry and freighter traffic) has been increasing (e.g., Osborne 1991). Whale watching in particular has raised a variety of concerns among researchers and members of the public about the potential for disturbance (Kruse 1991; Osborne 1991; Duffus and Dearden 1992, 1993; Phillips and Baird 1993; Duffus and Baird 1995; Burgin and Otis 1995; Baird et al. 1998b; Williams et al. 1998). Numerous behavioural changes have been reported in response to close approaches by boats, although some of the studies undertaken have serious methodological problems, causing researchers to question their validity (Duffus and Dearden 1993). Studies have focused both on northern *residents* in Johnstone Strait and southern *residents* in Haro Strait. A number of differences between these sites, the populations of whales which use them, the number and types of boats found in the two areas, and the research methodologies being used in each site, preclude any simple comparison of results from the two areas. Changes in behaviour in response to approach by boats have been demonstrated for northern *residents* (Trites et al. 1996; R. Williams, personal communication). Unfortunately the implications of such changes in behaviour on reproduction or mortality are unclear. While similar behavioural changes have not yet been demonstrated for southern *residents* (Osborne 1991; Burgin and Otis 1995; Baird et al. 1998b), there does appear to have been a substantial decrease in the proportion of time southern *residents* engage in resting behaviour during daylight hours, coincident with the large increase in whale watching activity (Osborne 1986; K. C. Balcomb, R. W. Osborne, personal communications). For *transient*

Killer Whales, Barrett-Lennard et al. (1996) suggested that vessel noise might impair their ability to detect prey. The impact of a single boat would appear negligible, as Baird and Dill (1996) found that under such circumstances observed food intake rates of *transients* were more than sufficient to account for the whale's energetic needs. However, at least in some areas of the province and at some times of the year, such impacts could be serious. In the last few years (since 1993), it is not uncommon for small groups of *transient* Killer Whales to be accompanied by 5–10 boats when travelling off the Victoria area during summer months (Baird, personal observations), and such large numbers of boats seem more likely to impact foraging success in the way suggested by Barrett-Lennard et al. (1996). In one area in Washington state, the number of vessels found around groups of southern *resident* Killer Whales has been increasing (Figure 5), and in 1997 groups were accompanied by an average of 25 vessels (only one quarter of which are commercial whale watching vessels) during daylight hours in the summer months (Baird et al. 1998b; Figure 6). The commercial whale watching fleet in the area (including the ports of Victoria, Sidney and Sooke in British Columbia, and Bellingham and Friday Harbor in Washington) has been increasing rapidly, and numbered over 80 boats in 1997 (Baird et al. 1998b). As noted above (see Protection, National), levels of awareness of, and adherence to, whale watching guidelines are largely unknown (except in a few specific localities during summer months), and virtually no official monitoring or enforcement of whale watching guidelines takes place.

A more direct impact of boats on whales involves injuries or deaths from collisions. Considering the large number of vessels interacting with Killer Whales during the summer months in British Columbia, vessel collisions are extremely rare. One well-documented case in British Columbia has been reported (Anonymous 1974), with an animal apparently fatally wounded after a collision with a large vessel (a ferry). Ford et al. (1994a) note the animal struck may have been part of the northern *resident* population. Several other live animals have been seen with scars that might be attributable to vessel interactions, although the evidence for this is inconclusive. One vessel collision with a southern *resident* Killer Whale in Haro Strait, Washington, was witnessed in 1998 (V. Shore, personal communication), but the vessel was moving slowly and the animal did not appear to be injured as a result of the collision. A northern *resident* was struck by a speed boat in 1995 and received a wound to the dorsal fin, which appeared to heal quickly (P. Spong, H. Symonds, personal communications).

The generation of loud underwater sounds through such sources as acoustic deterrent devices ("seal scar-

ers" or ADDs) at aquaculture operations also has the potential to cause disruption of movement patterns or even abandonment of an area (Morton and Symonds 1998*). Morton and Symonds (1998*) noted a drastic reduction of use of the Broughton Archipelago, off northeastern Vancouver Island, by both *resident* and *transient* Killer Whales, coincident with the installation of several high amplitude ADDs in the area. *Residents* have shown a decline in use of the area (measured as number of days per year observed) of over 75%, while *transient* use of the area has declined by over 50%. The lesser decline by *transients* may be due to their use of specific channels in the area away from the ADDs (Morton and Symonds 1998*). Morton and Symonds (1998*) compared use of the Broughton Archipelago with the nearby Johnstone Strait, an area where no ADDs were in use, and where *resident* use of the area has been more-or-less stable over the same periods. Their study provides evidence of Killer Whale avoidance of areas where ADDs were in operation (Nichol and Sowden 1995 present information on avoidance of another species), thus potential effects by their use by other aquaculture facilities on the British Columbia coast should be studied, and increased use of such devices should be strictly regulated.

More critical conservation problems concern two general areas, the effect of pollutants and the reduction of the prey base due to anthropogenic activities. Two general groups of pollutants warrant discussion: (1) persistent toxic chemicals which bioaccumulate; and (2) petroleum products. Killer Whales from British Columbia and neighboring areas have been shown to accumulate high levels of persistent toxic contaminants (Calambokidis et al. 1990; Jarman et al. 1996; Matkin et al. 1998; Ross et al. 1998). Populations of *resident* Killer Whales in British Columbia spend a large proportion of their time in near-shore waters in close proximity to various sources of pollutants. A recent study using samples collected from free-ranging southern *residents* demonstrated that levels of PCBs and PCDD/Fs in these animals were three times higher than levels known to be immunotoxic for harbour seals (Ross et al. 1998). Levels in individual southern *residents* were three to five times higher than in individuals of equivalent age/sex classes of northern *residents* (P. Ross, personal communication), which live in an area with far fewer sources of pollutants (see Evaluation). *Transients* appear to spend less time in highly polluted areas, but feed almost exclusively on marine mammals, so may accumulate higher levels of many toxins. Matkin et al. (1998) note that levels of PCBs and DDTs in *transients* from Prince William Sound were 14 and 22 times higher, respectively, than for *residents* from the same area. They also note that the group of *transients* with high levels have shown no recruitment since 1984, suggesting

that there may be a linkage between the low rate of reproduction and the high contaminant levels. Although sample sizes are smaller and based on stranded animals, levels of mercury appear to be higher in the tissues of *residents* than *transients* (Langelier et al. 1990). One possible candidate for these high levels of toxins in *residents* is consumption of heavily contaminated prey, but consumption of such prey has not become apparent in the studies of foraging undertaken to date. The high levels found in southern *residents* could affect reproduction, immune function and endocrine function (Ross et al. 1996a, 1996b, 1998). Reproductive or endocrine function impacts fall into the long-term category of effect. Immune function affects can result in acute (immediate) impacts on individuals or on the population. For example, it is thought that the 1988 morbillivirus-associated mass mortality of harbour seals in northern Europe, which resulted in a population reduction of over 50%, was exacerbated by such immunotoxic effects of contaminants (Ross et al. 1996a, 1996b; de Swart et al. 1996).

Large-scale dumping of oil has the potential for detrimental effects on Killer Whale populations. Concurrent with the *Exxon Valdez* spill in Prince William Sound, Alaska, was the unprecedented loss of 14 Killer Whales from one pod which was seen in the area immediately following the spill (Matkin et al. 1994). Dahlheim and Matkin (1994) reviewed the evidence for a cause-and-effect relationship between the spill and the deaths of these whales, and conclude that while there was a strong spatial and temporal correlation between these events, insufficient evidence is available to determine whether the spill caused the deaths, or other factors, particularly fisheries interactions, were responsible. Given the large amount of tanker traffic on the British Columbia and Washington coasts, there is a potential for the loss of a large proportion of a population. In Juan de Fuca Strait, tanker traffic has been increasing, and tankers are aging (existing tankers are not expected to be phased out and replaced with double-hulled tankers until 2015; F. Felleman, personal communication). Thus a population such as the southern *residents* (considering their tendency to congregate in one area during the summer months) may be at risk from a major spill.

It is beyond the scope of this review to undertake an assessment of trends in the abundance of all the potential prey species of Killer Whales, and in fact it is likely that such an assessment is impossible (or nearly so) given the data that are available. Regardless, in terms of a reduction in the prey base available for Killer Whales, it is clear that at least some of the populations of prey species of Killer Whales are substantially smaller today than historically. In terms of salmon, anthropogenic influences on populations have included destruction, degrada-

tion and/or prevention of access to breeding habitat through urbanization, slides associated with road or railroad building, dam building, forestry and agriculture, as well as a reduction in numbers through fishing (Groot and Margolis 1991; Nehlsen et al. 1991; Slaney et al. 1996). Recent reviews of stocks from southeast Alaska through to California document large-scale reductions in many stocks, and extinction of others (Nehlsen et al. 1991; Baker et al. 1996; Slaney et al. 1996; see also e.g., Holtby and Finnegan 1997*; Wood et al. 1997*; Bradford 1998; Rutherford et al. 1998*). These reviews focus primarily on evaluating which stocks are at risk of extinction. Killer Whales will be affected by a simple reduction in numbers, rather than only an extinction of stocks. Within British Columbia, the salmon populations most drastically impacted are those in the southern part of the province, particularly the Strait of Georgia (Slaney et al. 1996), coinciding with the population of Killer Whales (southern *residents*) which seems most at risk (see Population Size and Trends, and Evaluation). Some evidence is also available for declines of other potential prey species (e.g., Fargo 1997*; Leaman and McFarlane 1997*; Stanley and Haist 1997*; Ware 1997*; Yamanaka and Kronlund 1997*). Reduced prey availability could result in an increase in the amount of time whales would need to spend foraging, potentially leading to reduced reproductive rates and/or increased mortality rates. Insufficient information is available to assess whether such impacts are currently manifest. Given the inherent difficulty of determining such impacts even if they exist, and the potentially large role they might have on increasing mortality or decreasing reproductive rates, a precautionary approach is warranted (Richards and Maguire 1998).

Special Significance

Among the cetaceans, Killer Whales exhibit several unusual features related to social organization and behaviour. One is the presence of the two sympatric populations (*residents* and *transients*) in the nearshore waters of the eastern North Pacific, each specializing on different prey types, and differing in behaviour, acoustics, and morphology (Baird and Stacey 1988; Bain 1989; Ford and Hubbard-Morton 1989; Morton 1990). Such a situation, with foraging specializations occurring among sympatric populations, is unusual for mammals, as well as for vertebrates in general (see Mayr 1996; Otte and Endler 1989). This system may provide valuable information on the causes and consequences of reproductive isolation between populations (Baird 1994).

One apparent consequence of the differences in diet between the two forms are differences in dispersal patterns. For *residents* no dispersal of either sex occurs; individuals travel in long-term stable groups

comprised of several maternal lineages. This situation has not been documented for any other population of cetacean, or any other species of non-human mammal. For *transients*, dispersal of most individuals of both sexes from the maternal group occurs, though not all male offspring seem to disperse (Baird 1994, 1995b, 1998; Baird and Whitehead 2000). Such variability in dispersal patterns between sympatric populations of closely related animals provides a unique opportunity for examining some of the costs and benefits of group living.

The types of foraging specialization found in populations in the eastern North Pacific may also occur elsewhere in the world, though research efforts elsewhere have been generally insufficient to determine whether sympatric forms specializing on different prey types exist. Individuals of some populations feed almost exclusively on other marine mammals. Such predation on marine mammals makes the study of foraging behaviour easier than perhaps for any other species of cetacean. Several interesting findings have come from these studies, including evidence that females teach hunting skills to their offspring (Lopez and Lopez 1985; Guinet 1991b; Guinet and Bouvier 1995), and also a strong relationship between group size and foraging success in one population (Baird and Dill 1996).

Besides these intrinsic characteristics, Killer Whales also hold an unusual fascination for humans. Such fascination is reflected in the large attendance figures at aquaria which hold Killer Whales around the world, through the demand for commercial excursions to see these animals in the wild, and through the large number of popular books, magazine articles and films which have been devoted towards these animals. In the Haro Strait region, a trans-boundary area between Washington state and British Columbia, a large and growing whale watching industry focused on this species exists (Baird et al. 1998b; Figure 5). Ticket sales for this area (in both the U.S. and Canada combined) were estimated to be approximately 5.5 million (U.S.) dollars in 1997 (R.W. Osborne, personal communication).

Evaluation

The taxon *Orcinus* has been evaluated by the IUCN Cetacean Specialist Group, and designated as Lower Risk: Conservation Dependent (IUCN 1996). This category, effectively one level below the IUCN Vulnerable category (which includes species facing a high risk of extinction in the wild in the medium-term future), includes species which are the focus of a continuing conservation program, the cessation of which would result in qualifying for one of the higher (e.g., Vulnerable) categories within a period of five years (IUCN 1996). The COSEWIC classification of "Endangered" is for species "facing imminent extirpation or extinction", "Threatened" is for

species that are "likely to become endangered if limiting factors are not reversed", and "Vulnerable" is for those species "of special concern because of characteristics which make [them] particularly sensitive to human activities or natural events" (Campbell 1996). The COSEWIC definition of "species" is particularly important in evaluation of the status of Killer Whales, as it explicitly includes any "subspecies, variety or geographically defined population[s]". Evidence is summarized below regarding Killer Whale populations in Canada relevant to such classification.

Off the British Columbia coast, Killer Whales are subdivided into a number of populations, and these populations are distinct genetically, morphologically, and behaviourally (see e.g., Table 1). Based both on these biological characteristics and the COSEWIC "species" definition, it is clear that these populations could warrant independent evaluation and classification, where appropriate (it should also be noted that these populations are evaluated and listed independently in the U.S. — Barlow et al. 1997; Hill et al. 1997). One of the British Columbia populations, the "northern" *residents*, has been growing since the end of live-capture fisheries in the early 1970s, but the population in British Columbia only numbers just over 200 individuals. The "southern" *residents* have not shown a steady increase, and the population size has declined by 10% in the last three years (1996–1998), to a level below that prior to live-captures (Figure 6). This decline is due to an increase in mortality rate, particularly mortality of adult females. The cause or causes of this increase in mortality are unclear, but there are several possibilities (Table 3). The core area for southern *residents* (Haro Strait) is bounded by the cities of Vancouver, Victoria and Seattle, with over 5.5 million people living in the area, increasing numbers of commercial and recreational vessel traffic, and numerous sources of pollutants. It seems unlikely that either pollution of these waters or vessel traffic will decrease in the near future. Southern *residents* have toxic chemical levels three times higher than levels known to cause immunotoxicity in Harbour Seals, and the most immediate anthropogenic risk to these populations is likely immunotoxic effects from this accumulation of persistent toxic chemicals (see Ross et al. 1996a, 1996b, 1998). Potential impacts of a reduction in prey populations and increasing numbers of commercial and recreational whale watching boats (Figure 5) may also be serious threats, although insufficient information is available to evaluate the magnitude of these threats. In terms of reduction of salmon populations, numbers in the Strait of Georgia, where the southern *residents* spend a large proportion of their time, have been reduced to a larger extent than populations elsewhere in British Columbia (Slaney et al. 1996).

For *transient* and "offshore" Killer Whales in British Columbia, no population trend information is available, though, as with both northern and southern *residents*, population sizes appear to be small. *Transients* feed high on the food web, and are likely also at risk from high levels of contamination by persistent toxins. For Killer Whales in the Canadian Arctic and Atlantic, no information on population identity or trends is available, though populations appear to be very small, and the threats which face British Columbia populations likely also impact eastern Canadian and Arctic populations. Because of their small population sizes (in the low hundreds), Killer Whales are also at risk from natural events (e.g., entrapment or mass stranding) which could drastically impact a local population.

From the above, it is clear that all populations of Killer Whales in Canadian waters should, at the minimum, be considered vulnerable. The only question that remains is whether one of the populations, the southern *residents*, should be considered threatened. The population is extremely small (89 individuals in 1998), has declined by 10% in three years due to an increase in mortality rates, and several threats have been identified which have the potential to cause this population to become endangered. As noted, it is unlikely that at least some of these threats (pollutants, vessel traffic) will be reversed in the foreseeable future. While it is unclear whether the recent (1996–1998) decline is directly due to these anthropogenic factors, or whether the population will continue to decrease, the rate at which this population has declined demonstrates how quickly such a population could become in danger of extirpation. That the threats to the population are insidious, difficult to quantify, and even harder to rectify, all warrant a conservative (precautionary) approach to management (see Richards and Maguire 1998). Without a COSEWIC designation, it seems unlikely that anything will be done regarding mitigation of these impacts, and the population could become endangered well before another evaluation is undertaken. Since the population is a trans-boundary stock, efforts to coordinate actions with U.S. management agencies are also required.

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Book Reviews

ZOOLOGY

Birder's Mexico

By Roland Wauer. 1999. Texas A&M University Press, College Station, Texas. xxvi + 304 pp., illus. Paper \$18.95.

The author is a retired National Park Service ranger from Texas. During his life he has had ample opportunity to visit Mexico and to study the Mexican specialties that spill over onto the U.S. side of the border. In this book he displays his affinity to Mexico's flora, fauna, and people. As this book is about wild places, the issues that normally pepper travel accounts, like crime and poverty, are replaced by a sense of hospitality and friendliness from Mexico's rural inhabitants.

The book is divided into sections that describe the four major regions of Mexico, running from north to south. The author has selected to describe, within each region, a handful of specific areas, visited by him in the past. Although the book's title suggests this work is on birds, it contains a lot of information on plant life. While this is not a detailed plant account, the author gives a good sense of the general habitat type. Some plants are specifically identified because they are key species, and they help in defining the distinct environment used by particular species of birds. The book has a number of half page, black-and-white illustrations. Most of these are habitat photographs or scenery shots related to vegetation. Wauer also notes any interesting mammal or reptile sightings.

Wauer describes the trips he has made during 30 years to some of Mexico's best birding places, both as a professional and an ardent birder. Often he searched for a specific rarity or group of rarities. He describes the locality and how to get there. The author adds practical travel advice on restaurants, hotels, ferries, gas stations, and the like. He warns of rough roads and any problem associated with a remote locality. He does not mention any problem with wild beasts, not even ticks and mosquitoes. I presume the area is too dry for bugs and the other so-called dangerous animals rarely bother anyone.

When searching for a bird the author's description reveals much about the bird's habits and habitat. He generally adds a short list of significant birds; local specialties, rare and unusual finds, etc. Indeed he has

added a plant list just before the bibliography but the book does not contain an exhaustive bird checklist.

The author has one habit I found tedious. He repeats references and similar material in full, every time. For example, he uses Jerry Radz *Flora de Mexico* as a reference throughout his travels. This book is referenced in full repeatedly. I would have preferred the more normal superscript [¹] method, or at least "(Radz 19)". Similarly he makes reference to other chapters as "Chapter X The slender-billed Wren" rather than "(chapter X)". The author includes the names and home localities of all his companions for every trip. While it is nice to be mentioned in print, for those of us outside this group of friends name repetition is tiresome. The trip participants could have been covered in an appendix. I would have preferred the author had used capitals for each species. I recognize this is not considered correct grammar by some, but it makes the species name more obvious (that is a "brownish graceful mockingbird" becomes a "brownish Graceful Mockingbird." In the second case it is evident which is an adjective and which is the bird's name.)

This book was lots of fun to read. The author clearly enjoyed the exploration of Mexico's wild places and his contact with the locals and this sense of endearment came through in his writing. Like any good book it was easy to put yourself in the author's shoes and feel a part of his adventure. The descriptions of the habitat give a good sense of the countryside, without being heavy and cumbersome. The reader can easily share his delight and sense of discovery when he finds a target bird.

While this is a good fireside book, it will also be useful to anyone visiting Mexico (and probably Mexican residents too.) However for some of the species at risk his directions are quite spartan. I suspect this is deliberate. Any worthy birder should be able to fill in the gaps, whereas a less desirable visitor would find the route only with great difficulty.

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The Destruction of the Bison

By Andrew C. Isenberg. 2000. Cambridge University Press, New York. 206 pp., illus. U.S. \$29.95.

As I began to read this book, I wondered, "What could possibly be added to the story of bison ecology and extermination not already presented in Frank Roe's masterful 957-page compendium, *The North American Buffalo: A Critical Study of the Species in its Wild State* (University of Toronto Press, 1951)?" The answer is: Quite a lot. Isenberg deals more extensively with the socio-cultural aspects, especially recent studies in social, cultural, labour, and gender history. As he says, "Insights from those fields suggest far greater complexities in the relationships of Indians and Euroamericans to the bison than historians formerly supposed."

Unfortunately, Isenberg's summations are almost exclusively restricted to affairs south of the 49th parallel. He tells nothing about the more symbiotic relations between Indians and fur traders in Canada, and makes no mention of the arrival of the Canadian Pacific Railway. His sweeping generalization that "The fur trade on the western plains emerged from the spread of horses" would be less true for western Canada, where the appearance of guns and steel traps was perhaps more important than the advent of the horse, and furs were more readily transported by canoe.

Isenberg believes that ecological and economic changes were inseparable on the plains in the 18th century. "Horses and smallpox — an Old World animal and an Old World disease — destroyed the dominance of the Missouri River villagers and levered the nomads to power in the grasslands. ... The bison liberated and empowered the plains nomads. ...[its] flesh served as food, its skin as clothing and lodging, its sinew as thread, its horns and bones as tools, even dried bison manure served as fuel." The annual harvest was six or seven bison per person per year. But, by selling their furs to the Euroamerican market, the aboriginals "bound their fate to the Euroamerican economic and ecologic context." Nevertheless, the ethic of communal cooperation, necessitated by the

precariousness of subsistence, together with their nomadic habits, caused the Indians to disdain the accumulation of property.

During the 19th century, bison robes supplanted beaver pelts as the prime object of trade. In 1825, 184,000 robes were shipped through New Orleans; in 1847, 110,000 hides through St. Louis; in 1872-73, about 400,000 hides out of Dodge City. Hunters wounded two or three bison for every one they killed. This carnage, augmented by anthrax among bison, 1821-31, smallpox among Indians in 1837-40 and cholera in 1849-50, and by drought in the decade after 1846, all combined to speed the eradication of a bison-based way of native life. The extension of the Northern Pacific Railroad into Montana, in 1881, administered the coup-de-grace for the northern populations of bison. With the advent of railroads, bison were replaced by domestic cattle, viewed by many as a "victory for civilization. ... not justice but destiny." The result for natives was poverty, misery and loss of a way of life.

By 1904, bison were so scarce that surviving animals were worth \$1000 each. Michel Pablo sold his Montana bison herd to Elk Island and Buffalo National Parks in Alberta for \$245 apiece. The dominant animal species in the largest biome of the continent had disappeared. Isenberg concludes that the debacle of bison disappearance "exposed the fragility of all societies ... that rely on the unsustainable exploitation of nature."

This thoroughly researched book is highly recommended. It provides a wide literature review, is complementary to Roe's 1951 book, will be a resource for geography, history, or native studies courses, and is an appropriate gift for anyone interested in the broad range of topics of bison, horses and native Americans.

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Prairie Birds: Fragile Splendor in the Great Plains

Paul A. Johnsgard. 2001. University Press of Kansas. Lawrence, Kansas. 331 pp., illus. \$29.95 U.S.

Paul Johnsgard is the most prolific author in ornithology today, writing more than a book per year. He obviously enjoys the literature searches and the writing, a winning formula. He writes well, often with a rhapsodical, poetic flavour. Reminiscences of his personal experience with each species are especially well done. His talents do not end there, for he

is an artist as well; his sketches of each species are exquisite. The maps and tables are helpful, especially data on breeding densities in tables 10 and 11. The blurb on the dust-cover of this book tells the truth: "written from the heart by a master of both birds and words."

No one is perfect. Johnsgard is reviled by a wildlife librarian of my acquaintance; when graduate students bring her lists of references containing erro-

neous years or volume or page numbers, or misspelled author's names, she asks at once, "Which Johnsgard book did you get these from?" Perhaps his speed of preparation militates against careful checking and revision. In this volume, Borrer, Growe, Means, and Weins are misspellings for Borrer, Grewe, Mearns, and Wiens. The chapter on furtive grass sparrows lists Knapton's three important papers on Clay-colored Sparrows under both Grasshopper and Vesper Sparrow, but not under Clay-colored Sparrow where they belong. David Duncan and Margaret Skeel's data on Sprague's Pipit numbers in Saskatchewan are not cited in references or in acknowledgements. There are minor errors in several tables (e.g., the highest North American densities involve six not seven North Dakota species and four not five Saskatchewan species). An occasional reader will be confused by the incorrect name of Breeding Bird Surveys, correctly used elsewhere, also being given to Breeding Bird Censuses (a study of a small area done several times each year).

Johnsgard admits to being highly selective in his choice of references, but in general he has surveyed

the literature well. Nevertheless, I detected occasional sweeping generalizations ("grassland soils are the most fertile on earth"), historical misrepresentations (the common or vernacular name of both the Franklin's Gull and Wilson's Phalarope derived from Dr. John Richardson's 1820s Saskatchewan River specimens, even though both later lost their priority as "type specimens"), physiological misunderstandings (owls cannot see in total darkness), habitat omissions (he fails to tell us that the Bobolink prefers wet meadows), and population oversights (no mention of the precipitous decline of Burrowing Owl populations in western Canada).

More than for any other bird guild, a high proportion of grassland bird species are showing population declines. This fact alone makes it important for birders and ecologists to understand these grassland species. Caveats aside, this readable and informative book is an excellent place to start.

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Ecology and Management of Large Mammals in North America

Edited by Stephen Desmarais and Paul R. Krausman. 2000. Prentice-Hall, Upper Saddle River, New Jersey. 778 pp., illus. U.S. \$59.95.

The Wildlife Management Institute (WMI), based in Washington, DC, is a private, nonprofit, scientific, and educational organization committed to the conservation, enhancement, and professional management of North America's wildlife and other natural resources. In 1978, the WMI brought together a group of North American wildlife biologists to produce a classic in the field of wildlife management: *Big Game of North America — Ecology and Management*, compiled and edited by John Schmidt and Douglas Gilbert. This text, published by Stackpole Books (Emmaus, Pennsylvania), was standard issue through three print runs to students in Wildlife Management courses from the time it first appeared until it went out of print a few years ago. I first encountered the book as a Wildlife Technician in Labrador in the early 1980s, but then went on to read it cover-to-cover during a course in Management of Large Mammals at the University of Minnesota in 1988. Schmidt and Gilbert's *Big Game* was a compendium that strove to be the 'authoritative volume' on the status, management, and future of large mammals in North America. It certainly succeeded, and was deserving of the praise and awards that it has received over the past two decades.

However, the science of wildlife management (or

wildlife ecology, whichever you prefer) has progressed considerably since 1978, and the status of many of our large mammals has changed. Even the name 'big game' has fallen out of use and has been replaced with 'large mammals' — for example, the course I took at Minnesota had been called Big Game Management until 1987. The WMI decided that too much of the information in Schmidt and Gilbert was dated, or even misleading, and did not proceed with a fourth printing, much to the consternation of those university lecturers and professors that taught wildlife management and ecology.

Paul Krausman (Professor, Wildlife and Fisheries Ecology, University of Arizona) and Stephen Desmarais (Associate Professor, Wildlife Management, Mississippi State University), were among those university faculty that were frustrated by the "out of print" status of Schmidt and Gilbert's text. The current WMI Vice-President, Richard McCabe, suggested to Desmarais and Krausman that they spearhead a project to produce a replacement text for *Big Game* with a commercial publisher. Following Schmidt and Gilbert's lead, Desmarais and Krausman solicited a select group of the continent's experts on individual species or management-related topics that were willing to share their time and expertise by writing separate chapters. They provided this list, along with a proposal and book outline, to the WMI and received its wholehearted encouragement and endorsement.

The result is *Ecology and Management of Large Mammals* and the editors have again succeeded in providing "a valuable textbook and reference for students and a record of contemporary practices for wildlife historians."

Ecology and Management of Large Mammals consists of 778 pages and 33 chapters written by 52 contributors (including the two editors). It can be divided into two main sections: Chapters 1 to 15 cover a variety of topics related to various aspects of large mammal ecology and management and Chapters 16 to 32 are detailed accounts of individual species native to North America, while Chapter 33 covers exotic species. In contrast, Schmidt and Gilbert (1978) had 494 pages, 27 chapters and 2 appendices, and was written by 28 authors.

The topic chapters include: Taxonomy and Conservation of Biodiversity, Human Values, Population Parameters and Estimation, Population Modelling, Nutritional Ecology, Carrying Capacity, Behaviour, Harvest Management, Genetics, Ranching, and Management on Tribal Lands. Chapters on Predators and Predator Control and on Habitat Management that were included in the 1978 book are noticeably absent from the new volume. The former is hardly surprising, given changes to the North American public's view of predators and predation in natural systems, whereas the lack of an overview on management of habitats does seem to be a considerable oversight on the editors' part. After all, the founder of the discipline we now call wildlife management, Professor Aldo Leopold, pointed out that habitat management (i.e., control of food and cover) is the highest and most intensive of his five levels of wildlife management.

Some of the first 15 chapters are more "cook-book" in nature and provide overviews of the methods used by wildlife biologists to obtain estimates of various population parameters, such as population size, age and sex ratios, mortality, etc. Much of this information can be found in other texts aimed at undergraduate and graduate students in wildlife and ecology. However, it is still valuable that these topics are included in this volume since so much of the efforts of wildlife biologists and managers across the continent are devoted to these areas. I found the chapters on Human Values, Human Dimensions and Conflict Resolution, Game Ranching, Management on Tribal Lands, and the history of large mammal management to be the most interesting, although the treatment of some of the subjects is rather sparse and, naturally, has the United States as the main focus. For example, Czech's chapter on aboriginal peoples and wildlife management barely touches on the co-management regimes now in place across much of northern Canada and where he does write

about Canada, he refers to the Inuit as 'Inuits.' White's chapter on ranching and sport hunting provides much food-for-thought, with statements such as: "Big game farming has a bright future in Canada" providing a lively springboard for debate among both wildlife professionals and the general public!

The individual species chapters are likely to be the most appealing part of the book for most people. The account for each species generally includes taxonomy and distribution, life history, diet, behaviour, reproduction, population dynamics, habitat requirements, and management. The chapters for some species, such as moose and white-tailed deer, are more detailed than others on jaguar and muskox, for example, simply because so much more work has been done on moose and deer. Again, there is an understandable lack of detail in the information provided, since entire books have already been published on species such as moose, mountain sheep, white-tailed deer, and elk. The reference lists will point the student or reader who wishes to know more in the right direction to obtain information that could not be covered in each chapter. Overall, the chapter authors are to be commended for finding a balance between brevity and scope.

One feature I particularly liked in the layout of the book is that references are provided numerically in parentheses, as opposed to the more familiar author(s) and year within parentheses. This reference format makes reading the text substantially easier and a complete list of references is provided at the end of each chapter. Figures and tables are clear and generally add to the text. An appendix lists all common and scientific names of animals mentioned in the text and there is a comprehensive index.

Despite its rather daunting cost, this book will take its proper place as a much-referred to text on the shelves of wildlife professionals across Canada, the United States, and Mexico. It should also find its way into the hands of keen naturalists who wish to have a comprehensive overview of our large mammal species and the whole business we call wildlife management on our continent. The editors, chapter authors, and the WMI are all to be commended for providing this volume that should see us through at least the next two decades, or until such time as it becomes apparent that another revision is required.

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Handbook of the Birds of the World: Volume 6 Mousebirds to Hornbills

Edited by Josep del Hoyo, Andrew Elliot, and Jordi Sargatal. 2001. Lynx Edicions, Barcelona, Spain. 589 pp., illus.

The *Handbook of the Birds of the World* (HBOW) series marches solidly on. The new volume, number six (HBOW6), covers mousebirds to hornbills. This grouping includes the mousebirds, an African family of grey or brown cardinal-like birds with long tails. Then follows the stunningly coloured trogons and kingfishers. The next group is the very similar todies. These five species of red-throated green birds are found on Caribbean islands. The book continues with the motmots and their cousins the bee-eaters and rollers. Ground-rollers and Cuckoo-roller of Madagascar are unique genera in that unique island. All by itself in the genus *Upupa* is the Hoopoe. The six species of African woodhoopoes are the least flamboyant birds in this book, somewhat overshadowed by the hornbills who bring up the close of the book.

What can one say about such a book? The editors set their high standards five volumes earlier, and volume six maintains their pace. The species covered in this volume are among the most beautiful on earth. From the legendary Resplendent Quetzal to the graceful paradise-kingfishers you can expect to see some wonderful photographs and artwork. I searched thoroughly to find some errors, without success. If I did raise a question in my mind it generally revolved around the interpretation of a data set. For example, I checked many of the range maps and I did find some minor differences with my perceptions. Who was to say what is right? Birds move about and ranges change.

The text is authoritative, well researched and written in a clear, uniform style. The systematics, morphology, habitat requirements, the habits including feeding and reproduction, and the current conservation and status are described for each family.

If you have not encountered the mousebirds before, try reading the introductory section to this family. While the six species have a certain physical charm they are not as glamorous as their closest relatives, the trogons. Their image also suffers too from their being fairly common, and therefore "ordinary." Yet their habits set them apart from most other birds far more than brilliant colours. They are social ani-

mals. They are the meerkats of the avian world. They stay in groups, bathe in groups, and cuddle together for warmth and companionship. One will stand guard when others feed: a duty they share in turn. There is a fascinating photograph of a Red-faced Mousebird laid on its back on a branch, being preened by a second bird. Happily these intriguing little birds are not at risk. Indeed, their numbers are expanding as a result of human activity.

By contrast the flamboyant hornbills are much better known than the mousebirds. Their size and appearance have made them filmmaker's favourites. These big bizarre birds appear on nature shows more often than the more striking bee-eaters and trogons. While hornbills are sometimes cooperative like mousebirds, there are species in which the female walls herself into solitary confinement for the nesting period. The text gives a thorough account of these traits.

With each edition of HBOW the editors have included "Forewords" of increasing complexity. In HBOW6 the foreword is a 41-page essay on bioacoustics and a tribute to the late Luis Baptista. My own awakening to bioacoustics came when a researcher played the "insignificant" song of a Henslow's Sparrow (usually quoted as *tslik*). Played at one-eighth speed it is a complex and beautiful song. How do birds hear this? The foreword looks at a multiplicity of these types of questions and reveals how little we know about bird song. Indeed the margin is filled with a sequence of boxes containing questions raised by researchers from around the world. The summary of what we do know, or at least think we know, is most intriguing. This essay is up to date, containing references to the work of Dabelsteen, McGregor and others using Automatic Location Systems. However it does not include the nocturnal migrant work using automatic acoustical transient detection or the new and exciting autonomous airborne monitoring system. The essay is written from the avian viewpoint, so it does not cover the difficulties we humans have in perceiving birdsong.

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Threatened Birds of the World

Edited by A. Stattersfield and D. Capper. 2001. Lynx Edicions and Birdlife International, Barcelona, Spain. xii + 852 pp., illus. \$U.S.115.

"It was the best of books, it was the worst of books, it was the doctrine of wisdom, it was the appreciation of foolishness." (With full apologies to Charles Dickens.) This is certainly one of the best of books. It is perhaps the easiest-to-use reference book I have ever read. It is the worst of books because it contains accounts of well over a thousand species at risk. There are an additional 700 or so near threatened species, meaning there are close to 2000 species for which we should be concerned. The authors show wisdom in clearly stating we are the solution to the problem. They give us an appreciation of the foolishness with which we have treated our planet.

This book covers the species at risk from a global perspective and received input from a huge list of experts and collaborating organisations. As it responds to the global position, the Canadian list is only seven species long (Eskimo Curlew, Whooping Crane, Piping Plover, Mountain Plover, Marbled Murrelet, Sprague's Pipit, and Bicknell's Thrush). Some of the other species on the Committee on the Status of Endangered Wildlife in Canada's (COSEWIC) Canadian Species at Risk list of November 2000 are not included (for example Sage Grouse, Barn Owl, and Burrowing Owl). Obviously, while we are concerned over our heritage these birds are doing better elsewhere in the world. This list does clearly show where Canadian responsibilities lay.

This book also uses a more complex ranking of species status. These include "Extinct in the Wild" but with survivors in captivity, and "Critically Endangered" where extinction could occur in the near future. Spix's Macaw falls into the latter category with only one male in the wild (there are 60 captive-bred birds).

The species are shown two to a 30-cm × 21-cm (12 × 8 inch) page. There is a masthead with the species name in English and Latin and symbols to show its current status. There is a small 4 to 5 cm portrait of each bird, generally a male in breeding

plumage, and a range map. A brief introductory note is followed by an even briefer identification note. Basic statistics (population estimate, current range, habitat, etc.) are placed in a yellow box for easy reference. A more detailed discussion of range and population, ecology, threats, and conservation follows. Finally the authors present the short range targets to be achieved if the birds are to receive help. Lower risk species are covered by a short discussion only.

The authors have also summarized the status of species-at-risk by country, listing each bird according to their category. A world map to show the country location accompanies these summaries. I found this section very useful in providing a broad perspective. It is immediately obvious that the northern countries of South America (Brazil, Columbia, Ecuador, etc.) are the ones with the long lists of species at risk. The principle reason is loss of habitat. The book concludes with approximately 3000 references.

The opening 30 pages contain a summary of the whole conservation issue and how to use the many features of this book. Beside the vignette illustrations of each species, there are several full-page illustrations.

This book is well thought out, beautifully illustrated with crisp text and clear maps. What I like most is the ease of use. It is simple to find a bird and rapidly get a good understanding of its status and the issues involved. It will be of great value to researchers and workers in the conservation movement throughout the world. It will encapsulate an important milestone in our knowledge and, I sincerely hope, can be used in the efforts to preserve our global heritage. Birds are not constrained by our political boundaries. Therefore understanding their status on a global scale is essential and should promote cooperation between countries. We owe a round of applause to the authors and contributors for this important book.

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Research Techniques in Animal Ecology, Controversies and Consequences

Edited by Luigi Boitani and Todd K. Fuller. 2000. Columbia University Press, New York. 442 pp., illus.

This is definitely a book for scientists. But it is also a book for naturalists interested in animal ecology and involved in wildlife conservation issues. Though the language and concepts can, in places, be intimidating for non-scientists, the greater part of the book is straightforward enough to provide excellent

background to common issues and research techniques in animal ecology.

The editors — Luigi Boitani (University of Rome) and Todd K. Fuller (University of Massachusetts) — reveal in the preface that the book grew out of persistent frustrations they felt in their teaching and research work: that scientific literature regarding ecology is full of false assumptions and methodologi-

cal errors. This is not surprising, they concede, given the enormous complexity of ecological systems. But they also point out that ecology is rooted in the scientific method applied to observation and experimentation of natural facts, and that like any other discipline in the natural sciences, ecology can only benefit from scientific rigour.

And so they helped organize a workshop in 1996 which grew into this book: eleven chapters on such intriguing and diverse ecology research topics as hypothesis testing, effects of marking, delusions in habitat evaluation, GIS modelling of species distribution, estimating home ranges and territories, investigating food habits, detecting stability and causes of change in population density, monitoring populations, modelling predator-prey dynamics, analysing population viability, and measuring the dynamics of mammalian societies.

Any attempt on my part to describe this material would not do it justice, so let me tell you which chapters I found the most enlightening.

The first, "A Critical Review of the Effects of Marking on the Biology of Vertebrates" by Dennis L. Murray (University of Idaho) and Mark R. Fuller (USGS Forest and Rangeland Ecosystem Science Center) made me aware that data from marked individuals (distinguished, for example, by tagging, mutilation, or radiotransmitters) may be biased if the effects of the markers on that animal's life (mobility,

feeding, courtship, etc.) are not detected or dealt with. If generalizations regarding unmarked individuals and populations, as well as conservation decisions, are based on possibly biased data, the consequences could be significant.

From "Delusions in Habitat Evaluation", by David L. Garshelis (Minnesota Department of Natural Resources), I learned that the concept of habitat — its availability, the use animals make of it, the preferences they have, and the way these things are measured, sometimes based on false assumptions — is much more complex than meets the eye. For example, the most valuable habitat is not necessarily the place where animals spend the most time, and the best habitat is not necessarily where the highest densities of animals are found. Habitat research built on problematic assumptions can have considerable repercussions if it is the basis for management decisions and habitat manipulations.

These are the sorts of things naturalists should know. But they don't come across in the more popular, less scientific literature. That's why, every so often, it's worthwhile to work through a book like *Research Techniques in Animal Ecology, Controversies and Consequences*.

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The Sibley Guide to Birds

By David Allen Sibley. The National Audubon Society. 2000. Alfred A. Knopf, New York. 544 pp. illus.

Very occasionally a guide appears that so clearly sets a new standard both in concept and execution that the potential user decides at once to acquire it. There is no need to look over reviews, and balance its worth against existing volumes: it is clearly superior. This is such a book.

In case there are some birders out there who have not had an opportunity to examine the Sibley guide, some basic facts will set the stage. It covers 810 species, plus 350 regional forms, has over 6600 illustrations, and at 16 × 24 × 3 cm and over 1200 g is larger and heavier than any other North American guide, although no more unwieldy than, for example, the Panamanian guide, which I have carried around tucked into the back of my belt for days on end.

The most innovative parts of the book are the individual species accounts. Here, instead of the traditional layout with blocks of text on the page facing the plates, the two are combined. Typically up to four species are covered on each pair of facing pages, with the images arranged in vertical columns. Similar plumages and postures appear in the same

positions across the page. The top rows are usually devoted to the birds in flight, with images showing both upper and underwing. Then we find the birds seated, with young bird, adult female, and male positioned one above the other. This approach also allows for great flexibility, and Sibley uses it to the full. On owls, for example, the young birds pictured are fledglings, and subsequent images may portray colour variations, as in Barn and Barred, different postures, as in Long-eared, rear and front views, as in Boreal and Great Gray, and age variation, as in Snowy. Where distinctive races occur, as in Great Horned, then more space can be allocated, and a full-page treatment portrays four different regional forms. The Red-tailed Hawk, with a huge range of variation, receives two full pages and over 39 different images, most of them of the bird in flight.

The actual text is relatively limited. After a heading giving common and scientific names and measurements [including weight], there is a brief summary statement on the species' identification. Each account ends with a section on voice, with a small range map, and there is often an additional paragraph at the bottom of the page on some aspect of the

species not covered by the preceding material. The identification criteria, however, are covered principally by terse notes placed at appropriate points among the images themselves, usually with a line to indicate the feature being mentioned.

There are other innovations. I liked the family summaries, giving an overview of the genera and species being covered, and the small images in this section usually show the less-striking plumages of the family; hence, female ducks and basic-plumaged shorebirds. Then each page has a heading naming the species group covered, with a couple of lines of general information about them. In some cases where the text is inadequate to cover some special aspect of a species or group there are short added sections, on such topics as the identification of scaup, eiders and buteos, fall warblers, aerial displays of snipe and woodcock, and so on. I'm very type-oriented, and there are times when I felt some nuance seemed to call for more text, but generally the approach works very well.

There is a useful introduction, and bird topography is discussed and well-illustrated in an excellent seven page section showing shorebirds, gulls and duck, as well as the usual passerines, and including page on moult cycles.

The book is not without its faults, although most are minor. However, perhaps the most striking problem on first view is that some colour tints are inaccurate, with many of the russet shades too red and the grays too bluish. The latter is most serious on the gulls, and detracts from an otherwise excellent treatment. One can only hope that the publisher will correct this in the next edition.

Some difficulties are a product of the approach. The book is bulky, but after all, nowadays most field guides spend more time on a car seat than in a pocket. On the other hand, I have heard criticism that the images are too small. Indeed, many are small, but they do the job, and their abundance gives the user the lux-

ury of seeing a range of options from a difficult species, and not just one or two. There may be a few places where size might have been increased without loss of clarity, but on the whole space seems very well used.

I was less satisfied with the approach to "regional populations", as Sibley describes them. These are identified mainly by geographic terms, e.g. "West Taiga", or "Pacific", on the basis that the scientific names can be more confusing than helpful. Perhaps, but the birder will encounter these names anyway, and Sibley has now introduced yet another set of terms [with attendant confusion] to describe these plumages. For example, last fall I saw a very pale Great Horned Owl which was quite unlike any of Sibley's images, but very closely resembled the *sub-arcticus* illustration in another reference. Do I conclude that this race is not shown in Sibley, or [more likely] that the striking difference was just normal variation? I'd welcome the scientific names in small print somewhere near the appropriate images.

While quibbling, I'll note that some Canadian ranges are inaccurate [no winter Greater Scaup on the Great Lakes!], and it's possible to second-guess the handling of extreme rarities [no Smew, for example]. There are also other errors here and there, and some statements I disagree with, but such things are inevitable in a guide of this scope. None of this seriously detracts from what is a masterful accomplishment. Overall this is an outstanding book that can and will be used constantly by novice and veteran alike. Even the most experienced birder will learn much from it, and its abundance of new illustrations will be of enormous value in expanding the scope of field identification. I'm just sorry I didn't have it forty years ago!

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Ecotravellers' Wildlife Guide to Ecuador and its Galapagos Islands

By D. L. Pearson and L. Beletsky. 1999. Academic Press, San Diego. xiii + 485 pp., illus. U.S. \$27.95.

I was very fortunate to have the opportunity to take a two-week birding tour to the eastern Andes of Ecuador, along with my wife, Valerie Wyatt, in February of this year. Despite finding out that a "National State of Emergency" had been declared the day before we had left, we had a wonderful time tooling around the peaceful countryside in our four-wheel drive rental and would have been non-the-wiser of the "emergency" (mostly peaceful demonstrations) had we not read about it.

Being a very avid birder, I sometimes forget to

look at the "whole package" that nature offers. I was very pleased to be given a copy of the Ecotravellers' Wildlife Guide to Ecuador and its Galapagos Islands before I departed, for the purpose of this review. Perusing this book before I left, reading more about the plants, animals and geography of Ecuador while I was there, and finally, when wishing I was still in Ecuador, instead of just pining to return, I was happy and eager to read more about the wildlife I had just recently seen. I can say, with out a doubt, that this book enhanced my experience.

The book was written with the goal of providing the ecotourist one book to take along that would

allow field identification of the most commonly encountered plants and animals. It is a guide of breadth, not depth. The authors also wanted to give information on life history, behaviour and conservation status. Unlike most field guides, they also endeavoured to make it a good read; this it is.

Knowing more about the general landscape has many benefits. For example, instead of trying to point out the aracari, "in the tree...the TREE...the funny looking tree with umbrella like leaves" — we could say, "the aracari in the cecropia tree". A much more accurate and pleasurable way to observe and one that leads to a deeper understanding of interactions in the environment.

The book is split equally between the background information, 249 pages worth, and the identification plates, 96 colour plates in all. The text covers the geography and selected parks of Ecuador as well as natural histories of the amphibians, reptiles, birds, mammals, insects, and other arthropods with a separate section dealing with the Galapagos wildlife. The plates are nicely coloured and detailed with accompanying text to aid in identification. Although definitely not as bulky or awkward as carrying bird, plant, mammal, insect, reptile... guides, it is still a hefty book and too big to fit in any pocket.

Species descriptions include icons that, at a glance, indicate if the species is found in the habitat region(s) you plan to visit. As a planning tool, you could decide to visit a particular region based on the plants or animals you would be likely to see. Of further aid to your travel plans, parks and reserves are listed for simple cross-reference in each habitat region.

The book does not, and was not meant to stand

alone. As stated by the authors, a companion travel guide is essential so you will know how to get to the various reserves, what time of the year would be best to go and what to expect in terms of accommodations and amenities.

Although we only visited a few of the habitat regions, I found the selection of common species to be fairly representative, for our trip. However, with only 300 of Ecuador's nearly 1600 species of birds (for example) represented, it may have been useful to list similar species with the descriptions with a quick explanation of the relevant difference(s) in appearance. An example would be the Golden-headed (pictured) and the very similar Crested Quetzal (not pictured); a simple mentioning of the white undertail (male) or barred tail (female) of the latter in the text would have identified two birds with one picture. This could have been done without adding extra pages as most of the descriptive pages facing the plates are well endowed with white space.

If you are a serious nature observer, this is not the only book you will take. But as a supplement to fill in the gaps that all focused field guides leave, this is an excellent choice. The book provides a basic understanding of the ecology of Ecuador and the Galapagos in an enjoyable to read format. With a deeper understanding of the rich tapestry that makes up Ecuador, this book can help you to enhance what is almost sure to be a wonderful visit.

PAUL GRANT

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Belize and Northern Guatemala: The Ecotravellers' Wildlife Guide

By Les Beletsky. 1999. Academic Press, San Diego, California. 488 pp., illustrated. U.S. \$27.95

The purpose of this book is to both encourage "properly conducted" nature tourism in Belize and Northern Guatemala and to "provide ecotravellers with sufficient information to identify many common animal species and to learn about them and the families of animals to which they belong." To these ends, Beletsky is abundantly successful. The first few chapters consist of a detailed description of habitats, tropical ecology and terminology, major reserves, and the benefits of ecotourism, which provides an excellent base from which to start planning or preparing for a nature-oriented trip. The remaining bulk of the book focuses on meeting the second objective, in the form of a selective field guide. It includes 104 colour plates of the more common or spectacular species of birds, mammals, reptiles, amphibians, fish, coral, and jellyfish and line drawings of plants, as well as tantalizing

colour photographs of the main habitats. The text describes natural history, behaviour, status, description, and interesting notes on folklore and trivia for each animal family. The overall result is an easy-reading resource that creates excitement for the country before leaving on the trip and a better appreciation of the diversity of wildlife when there. I am not aware of any other book that fills such a niche for this geographical region.

Given the impossibility of including all species of wildlife, there is bound to be disagreement as to which species should have been included in the plates. I believe Beletsky has been as thorough as is feasible. Generally, the guide appears to include all the relatively abundant species as well as some Yucatan endemics, however, for more difficult groups of species the guide is less complete. For example, only one-quarter of the approximately 50 possible species of flycatchers are illustrated, whereas all but one of

the seldom seen tinamous are shown, presumably because they are especially interesting. I had the opportunity to bring this guide along on a recent trip to Belize and Tikal, a popular Guatemalan day trip for visitors to Belize. While I, as a serious birdwatcher, was sure to bring along a more comprehensive field guide to the birds, carrying a book that exceeds one kilogram is not for everyone. We used the Beletsky guide (at less than half the size) to identify numerous mammals, fish, and a snake.

The plates and text are well-done and accurate. However, I found some of the plates to be misleading in terms of relative proportion. Some, such as plates 40, 46, and 64, portray very differently sized birds, next to one another and in equal dimensions. Instead, actual measurements in centimetres and inches, are given in the text opposite each plate.

The book is attractive and appealing to naturalists

as well as less-experienced travellers. I made the mistake of taking this book out in the lunchroom at work, and was not able to retrieve it until everyone had a chance to flip through the plates and read the exotic names aloud. Although the experienced neotropical birdwatcher or researcher should consider this book as supplemental to more comprehensive resources, I would recommend this book as an excellent all-purpose field guide for the naturalist who wishes to be informed regarding the wildlife they are likely to see, as well as for the traveller who is interested in getting off the beaten path and wonders about what might be beyond the beach.

VALERIE WYATT

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Millions of Monarchs, Bunches of Beetles: How Bugs find Strength in Numbers

By Gilbert Waldbauer. 2000. Harvard University Press, Cambridge, Massachusetts. 264 pp., illus. U.S. \$24.95.

Dr. Waldbauer will be well-known to many bird-watchers for one of his other books: *"The Birder's Bug Book"*, which has helped to make birders aware that insects of the earth have functions other than providing meals for birds. His current book delves deeper into the lives of those Bugs, and what fascinating lives they are. The ingenuity and adaptability of insects to enhance their lifespan, to ensure their reproduction, to avoid predators and outwit those they predate upon is wondrous. The text is scientific and readable. It can be readily understood by someone who is observant and has spent time in the field or garden, and will enhance an understanding of the scheme of nature — and you certainly wonder if there is not a scheme from the descriptions in this text. The interdependency of all living things is well illustrated.

Separate chapters deal with the structures of the insect world such as: controlling the climate of their group homes — bees controlling hive temperature, for instance; defences; group living; and how insects find partners. One chapter describes the methods used to obtain and subdue food — they sting, mimic, trap, ambush, make group attacks, and build webs. If their target has defences, they devise strategies either to avoid them or to defeat rivals. Breeding is often timed to ensure that young insects will have suitable food available when they hatch. Four insects have chapters of their own — cicadas, tent caterpillars, mayflies, and ladybirds. If you have ever contemplated using ladybirds as a biological control in your garden, don't bother — they disperse away from the release site almost as soon as they are freed.

The longest chapter is devoted to the Monarch butterfly and reveals results of new research. In recent years, scientists have learned a great deal from radio transmitters attached to Monarch wings — an attachment which is in itself an incredible feat. It is believed that on migration they navigate by the sun and a "magnetic compass" in the body, similar to birds.

The butterflies which move south to Mexico or California in the fall die and it is their progeny which return north in spring, laying eggs en route.

The hatched young continue north. Most of the males die en route. There are concerns about a new threat: genetically modified corn is dangerous to Monarchs since the pollen, which contains Bt, blows onto milkweed leaves and kills the caterpillars. It is now conceded that all efforts to preserve the overwintering sites of monarchs in Mexico have failed. The area is supposed to be a protected ecological site. Guards have failed to protect the sites from illegal logging, and at the same time have kept out film crews, tourists, and scientists from witnessing the logging. The Monarch wintering area is only 60 square miles, but even that cannot be safeguarded.

The illustrations by Kathleen Brown-Wing are excellent. They are drawings in grey/white/black of magnified insects on their food or hatching plant. This is a fascinating book which will appeal to a wide audience.

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Behaviour and Conservation, Conservation Biology Series 2

Edited by L. Morris Gosling and William J. Sutherland. 2000. Cambridge University Press, London, UK. 438 pp., illus. Cloth U.S. \$90; paper U.S. \$39.95.

Number two in a series that links the advances made in behavioural ecology over the last 30 years with the relatively new discipline of conservation biology, this book will appeal to naturalists and scientists alike. It contains 19 papers by leading researchers working in particularly active areas of conservation biology. The first paper, written by the editors, outlines the advances in behavioural studies and their role in conservation. The remaining contributions are divided into the following four areas: conservation impact of people; habitat loss and fragmentation; sexual selection, threats and population viability; and conservation applications of behaviour.

"Life history characteristics and the conservation of migratory shorebirds," co-written by Theunis Piersma, of the Netherlands Institute for Sea Research and Centre for Ecological and Evolutionary Studies at the University of Groningen, and Allan J. Barker, of the Centre for Biodiversity and Conservation Biology at the Royal Ontario Museum (the only Canadian contributor to the book), is particularly interesting and easy to understand. It looks at various life history characteristics of shorebirds — from productivity, lifespan and gregariousness, to trophic specialization, immunospecialization, orientation mechanisms, and geographic bottlenecks — and what it all means in a world that is changing at an increasing rate. The authors finish by identifying pressing conservation issues and research needs.

"Controversy over behaviour and genetics in cheetah conservation," by Tim Caro, of the Department of Wildlife, Fish & Conservation Biology at the University of California at Davis, sheds new light on the environmental and genetic problems facing the world's small cheetah populations. Caro starts by outlining the genetic problems facing the cheetah, then goes on to examine misgivings over the genetic findings, review behavioural and demographic data in the wild, and discuss findings regarding juvenile mortality and disease among captive cheetah. It appears that the cheetah's ecological problems are more serious than its genetic uniformity.

"Retaining natural behaviour in captivity for re-introduction programmes," by Michael P. Wallace, of the San Diego Zoo, is a good overview, along with a number of case histories, of the behavioural considerations (life history strategy, sociality, imprinting) and management techniques (enriched environment, rearing approaches and soft vs. hard releases) that must be thoroughly understood for captive-bred progeny to be successfully released into the wild.

Scientists will be better able to understand the technical details of the more scientifically oriented papers, but naturalists who take the time to work their way through the book — at time labouriously, I must confess — will find the knowledge they gain well worth the effort.

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Turtle Conservation

Edited by Michael W. Klemens. 2000. Smithsonian Institution Press, Washington. xv + 334 pp., illus., \$57.75.

Turtles first evolved over 200 million years ago. They out-lived the dinosaurs, but there is increasing evidence that their future is bleak. Turtles' slow-and-steady-wins-the-evolutionary-race (late maturing, high egg and juvenile mortality, but very low adult mortality) approach to life is now working against them. Michael Klemens, director of the Metropolitan Conservation Alliance for the Bronx Zoo-based Wildlife Conservation Society, along with seventeen other experts on turtles and/or conservation provide a comprehensive analysis of the current threats facing turtles.

Turtle Conservation consists of 10 peer-reviewed papers. The first three chapters focus on major threats: habitat alteration, human use of turtles, and disease. The next four chapters deal with the major

ecological groups of turtles: sea turtles, river turtles, non-river freshwater turtles, and tortoises and other terrestrial turtles. The final three chapters examine various conservation actions: the use of genetics and demography, manipulating populations, and a summary chapter on developing effective conservation strategies.

The chapter on human use of turtles is particularly staggering. Many species are being eaten into extinction because of the growing demand in Asia for turtle meat. Vietnam alone exports over 200 000 turtles per year (page 42)! It is not just Asian species which are at risk. The USA commonly exports more than 30 000 softshell turtles a year, mainly to China and Japan (page 36). Those turtles which avoid the soup pot may still end up in the pet trade. Even a "developed" nation like the US legally imports over 30 000 turtles a year for the pet trade (page 56). This is particularly troubling when most adults sold in the pet

trade are wild-caught individuals. The level of illegal trade is unknown, but likely far greater than the legal amount.

Is this a perfect book? No. Although the focus of the book is global all the authors are American. In fairness, some of the authors have international experience, particularly Edward Moll who has worked on turtle conservation in Asia for over 20 years, and the book has many non-US case studies. Another oddity is that one-third of the authors all work for the Wildlife Conservation Society. A greater diversity of voices would have been beneficial.

In terms of content, all the papers are strong, but there are occasional weaknesses. The chapter on diseases suggests that chemical contaminants have been found in "at least one species" of turtle (page 86). This vague statement is just one example of less than exhaustive review of the existing literature on a particular subject. The chapter on demography and genetics rightly stresses the importance of carefully examining the age structure of a population before determining whether or not the population is viable. However, there is no mention whatsoever of the growing evidence that plastral growth lines can dramatically underestimate age. There is also virtually no mention anywhere in the book of the importance of hibernacula as critical habitat. Many species overwinter communally, possibly because optimal overwintering habitat is limited. Granted this may be a

temperate zone bias of my own, but it is relevant for many species around the world.

Despite these minor complaints this is a definitive guide to turtle conservation. Klemens' final chapter, "From information to action: developing more effective strategies to conserve turtles" is clear, insightful, and thorough. He makes a number of key recommendations, at the heart of which is controlling exploitation of turtles. A global moratorium on the turtle trade should be considered before species are lost. Ultimately, though, successful conservation of turtles (or other species) must be focused at the ecosystem or landscape level, not just the population level. Klemens provides the example of the Great Swamp in New York's Harlem Valley as an example of effective turtle conservation. He has involved local politicians in biological survey work. For these people, environmental rhetoric is replaced with the personal experience of seeing turtles moving far from wetlands into upland forests. This has resulted in growing interest in protecting the wetlands with large, meaningful buffer zones. If Klemens' book can encourage such actions elsewhere around the world it will definitely have served its purpose.

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The Pheasants of the World: Biology and Natural History

By Paul A Johnsgard. 2000. Second edition, Smithsonian Institution Press, Washington D.C. xvii + 398 pp., illus. U.S. \$50.

Paul Johnsgard is a prolific author of bird books. He has made a great contribution to the birding world by writing books on groups of birds such as Cranes, Grouse, Hummingbirds and so on. Indeed, about half of his vast output has been of this type of generic book. *Pheasants* follows in this tradition, covering 49 species of pheasants, jungle fowl, peafowl (*Phasianini*) and other large, colourful species most often thought of as pheasants. This book does not cover the smaller members of the pheasant family (*Phasianidae*) such as quail, grouse, ptarmigan, francolin, and snowcock. The English names used by the author may not conform to those used in other well-known guides, but there is a list of alternative names for each species.

The format is similar to many of his other books. He has collected all the information he could on each species, and massaged it into a logical format. In this case, this is a second edition and incorporates information from a database that has increased forty per-

cent since the original publication. Distribution maps and drawings have also changed substantially. The author has dropped the detailed plumage description of the first edition, feeling that this information is fully covered elsewhere.

The book is divided into two parts. The first twenty percent contains a generic description of pheasant family biology. This includes chapters on reproduction, distribution and behaviour, plus one chapter on aviculture — or more correctly the role of raised pheasants in conservation. (However, details of rearing pheasants are not given as these are more fully covered in books dedicated to aviculture.)

The second section gives the individual species accounts. In all, 49 species are covered by a detailed description of range, subspecies and variation, behaviour, ecology, and biology. The author also summarizes the current status and conservation outlook. For, despite mankind's fascination with these exotic birds, almost seventy percent are in some danger and there is still much that is not known. About forty-five of the species accounts have a range map showing distribution, while the rest are covered by a text description of their range. Not surprisingly the

most extensive account is that of the Ring-necked Pheasant. The information on the other species is variable. The author has made these accounts as detailed as possible, within the limits posed by the existing data. There is a short text on identification, but more space is given to the ecology, biology and social behaviour of these birds. The accounts finish with a synopsis of status and conservation.

A colour photograph of the male (both sexes in the case of the Great Argus) illustrates most of the species. As most of the specimens appear to be in a zoo-like setting the photographs and the birds are in top shape. A number of additional illustrations are taken from charming paintings by Joseph Wolfe, executed in the 1870s. In this case, both the male and female are shown. Display postures and details of sub-species are shown by black-and-white line drawings made by the author.

I think it is important that someone does what this author does; that is he collates disperse and disparate

data into a single coherent volume. I do not have access to the 500 references used by Jonhsgard, nor do I have the time to sift through and select the salient information. This author performs these tasks and does them well. I suspect it will not attract a huge audience. Pheasant breeders will want more depth (and will use the actual references) and birders will need less (and will be content with field guides). I hope there are enough readers in the middle who are willing to buy this book and encourage this prolific author to continue. Certainly it is a fine book for anyone interested in the birds themselves, and not just simply identifying them in the field. It is a good resource for students as well as a sound addition to any library.

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The Biology of Plethodontid Salamanders

Edited by Richard C. Bruce, Robert G. Jaeger, and Lynne D. Houck. 2000. Kluwer Academic/Plenum Publishers, New York. xiii + 485 pp., illus. US\$195.

Plethodontid (or lungless) salamanders make up the largest family of salamanders with some 350 or more species. These fascinating creatures have been the focus of many studies. The fourth "Conference on the Biology of Plethodontid Salamanders" was held in June 1998 at the Highlands Biological Station in North Carolina. Many of the papers first presented at that conference are collected together in this book. This is the first time that a formal proceedings has been published as a result of the conferences.

The book is divided into three sections. Part 1 consists of papers presented at a symposium at the conference held in honour of Richard Highton on his retirement. Highton's pioneering work on molecular systematics and speciation in plethodontid salamanders stretches back over 40 years. The symposium was entitled "Points of View on Defining and Naming Species of Plethodontid Salamanders." Five invited papers tackle these themes in a variety of different species groups. Highton himself has a paper on the *Plethodon jordani* and *P. glutinosus* complexes which clearly illustrates the difficulty in delineating species. As recently as the early 1980s both *P. jordani* and *P. glutinosus* were each considered to be a single variable species, yet Highton provides detailed evidence on geographic protein variation that both "species" may actually consist of up to 14 species in total. Part 1 concludes with a summary paper (not presented at the conference) on "Systematics at the turn of a century" by Stevan Arnold. It highlights some of the conceptual (and philosophical) controversies in systematics and suggests directions research may take in the 21st century to resolve some of these dilemmas. Debates on what constitutes a valid species are not new to systematics and new types of data, regarding allozymes and mtDNA sequences have not been able to resolve problems. Ultimately, it must be acknowledged that defining species and species boundaries is subjective, for species themselves are but "ephemeral fragments of a grand evolutionary continuum" (page 95).

Part 2 — "Evolutionary and Comparative Biology of Plethodontids" — contains eight papers on a broad range of topics. A number of the papers tackle the entire family of plethodontid salamanders, or large subgroups. Sexual size dimorphism is critically reviewed as is courtship and its relationship to form, function and phylogeny. The life history evolution and adaptive radiation of the hemidactyline salamanders is also examined. This small group of approximately 25 species continues to offer puzzles to systematists. Is the group monophyletic? If so it exhibits more life history variation than any other comparable vertebrate group. Other papers focus on single species, for example, maternal behaviour of *Desmognathus ocoee* and population cytogenetics of *Eurycea wilderae*.

The third part of the book focuses on the "Behavioral Ecology of Small Plethodonts." Most of these eight papers deal with the Redback Salamander, *Plethodon cinereus*, undoubtedly one of the best studied vertebrate species. A variety of

topics are explored including kin recognition, pheromonal attraction, and alternative mating strategies.

Despite the title of this book, the focus is primarily phylogeny and evolutionary history. There is growing evidence that salamanders, as well as anurans, are a significant part of the global amphibian decline, yet reading this book one is struck by the lack of papers on conservation biology. The token exception is a paper on using artificial coverboards to monitor Redback Salamanders.

The hefty price tag on this book makes one wonder whether publishing a conference proceedings

was a good idea. The cost will surely prevent many university libraries, not to mention most individuals, from acquiring the book. The Highton symposium could have been published as a special section of any number of journals thus preserving the group dynamic. Nonetheless, the papers in this volume are first rate and it is an important contribution to our understanding of the lungless salamanders.

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Birds of Europe

By Lars Svensson and Peter J. Grant, illustrations by Killian Mullarney and Dan Zetterström. 1999. Princeton Field Guides, Princeton University Press, Princeton, New Jersey. 400 pp., illus. Cloth U.S. \$39.50; paper U.S. \$29.95.

Another bird guide for an area already blessed with several excellent volumes may seem hardly worthy of comment, let alone review. But this is a field guide with a difference: conceived by the late Peter Grant and Killian Mullarney, and sixteen years in the making, it is arguably the best field guide ever produced. It certainly is by far the best I have ever seen, and it now sets a standard that must be met by future guides on both sides of the Atlantic.

What is so exceptional about it? I compared it with two leading guides, one from North America, the *National Geographic Guide*, and the other from Europe, Lars Jonsson's excellent *Birds of Europe*. The latter has been my own choice for a European guide, and I used it extensively on a recent trip to Greece. Hence I had ample opportunity to compare it with the current volume, which proved to be the guide of choice with all my British companions!

All three books are about the same size and format, although the Princeton Guide [PFG] is the shortest of the three, the result of a conscious decision by the authors. To cover 848 species in a book of this size demands both a small typeface and small images on the plates — I need reading glasses to use it — but these initial drawbacks are quickly overcome by the remarkable quality of both text and plates.

Comparing the three volumes in terms of the length of each entry and the number of images, I selected some species that occur reasonably often on both sides of the Atlantic. In general, PFG has more text and more images for each species than either of the other two guides, and in some cases more than double.

This, however, was just the beginning. Those

small images are consistently superbly executed, with short notes appended throughout to emphasize key points. One feature I particularly enjoyed was the use of numerous small vignettes to illustrate key features of behaviour. Thus, a Northern Fulmar floating on a cliff updraft, and another series of three birds over the sea illustrating "gliding on long stiff wings". The plate for this species also includes images of dark and light morph birds seated on the water, three [light, intermediate, and dark] in flight, upper surfaces, and a single bird undersurface; plus another vignette of a bird nesting on a cliff-face. Not all species receive quite as extensive a series of illustrations, but this is fairly typical for the most widespread. As there are between two and six species featured on each plate, these inevitably appear cluttered — until one comes to use them, when one finds a significant degree of consistency in the layout of each page. This allows ready comparison of the species grouped there, and one finds neat hairlines separating the images of different species, while dashed lines separate different races.

The text itself is particularly concise and well-organized, with intelligent use of italic to highlight important features. One has the sense it is written by someone who really knows the species being discussed: for example, under Short-eared Owl we are told that "In certain lights e.g. at dusk or overcast weather, can look surprisingly whitish", while under Tawny Owl [a dark-eyed species] one is warned that ". . . yellow-eyed species e.g. Long-eared Owl, can look dark-eyed at night in headlights owing to large pupils".

The introductory sections to various families or groups are another valuable innovation, additional to the usual section in the Introduction to the book. There is half a page of hints on "Watching Seabirds", a page on "Birds of Prey", while shorebirds ["Waders"] and Gulls each receive two pages with

useful information on molts, and the gulls section has an excellent plate illustrating the sequences of gull plumage over four years. On the other hand, the page for introduction for the *Sylviidae* Warblers covers the differences between the five major genera, a potential source of considerable confusion to the beginner.

In the past, one of the difficulties with field guides has been that there has been a dichotomy between the needs of the novice and those of the veteran. I do not think this is the case here: it is indeed most accessible to a beginner, but also answers the demands of the experienced birder.

I could go on, but the reader will have the picture. This is a superb guide, meticulously thought-

out, clearly and knowledgeably written, with the most consistently satisfying plates of any guide I have ever used. True, there is a minor glitch here and there [and I find some of the sound descriptions hard to come to terms with] but overall it's difficult to imagine how it could be improved! It will now be the essential guide for birding in Europe, and while I would not normally advocate such a book for North American use, perhaps this is an exception. This book is sheer delight. Get it!

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Hoofed Mammals of British Columbia

By David Shackleton. 1999. University of British Columbia Press and Royal British Columbia Museum, Vancouver. 268 pp., illus. \$24.95.

The Royal British Columbia Museum (RBCM) and the University of British Columbia (UBC) are co-publishing a series of six handbooks that replace the now out-of-print *The Mammals of British Columbia* (Cowan and Guiget 1965). Shackleton's volume on our westernmost province's hoofed mammals, or ungulates, is the third of this series. Since the first two handbooks on bats and on opossums, shrews, and moles appeared in 1993 and 1996, respectively, it appears that will take almost another decade to see the series' completion. However, after reading Shackleton's treatment of British Columbia's ungulates (a major component of any jurisdiction's "charismatic megafauna") I'd suggest to those amateur naturalists with a keen interest in the mammals of western Canada that it will be worth the rather lengthy wait.

In 1993, Brad Stelfox edited the excellent *Hoofed Mammals of Alberta* with chapters written by a collection of that province's leading mammalogists each of whom addressed their own particular specialty. In my office, Stelfox's book remains a much-used reference for its well-researched chapters that examine all aspects of the ecology of ungulates. But, as a handbook to throw into a backpack or vehicle when heading out on a trip, it is not exactly suitable given its hard cover and size (22 × 29 cm). In contrast, *Hoofed Mammals of British Columbia* is much more field friendly with its well-bound softcover and compact size (14 × 22 cm). It is also written for a quite different target audience with none of the discussions on hunting, economics, and game ranching that are central to the Alberta book. The RBCM and UBC Press have obviously targeted this series at weekend to serious amateur naturalists who want a

well-written overview of the general biology of the particular mammal group with specific information on individual species and subspecies.

The first 43 pages of this handbook cover General Biology and include brief discussions on such topics as the evolution of ungulates, group living, food habits, mineral requirements, social behaviour, and reproduction. This is all done in a light and easy-to-read manner accompanied by 27 black-and-white pictures and diagrams. More serious students of natural history will no doubt often find themselves wanting more information than Shackleton provides; however, I believe that he has done an admirable job in giving just enough to answer some of readers' questions (and likely leading to a few more) without getting overly bogged down in detail. To assist the more adventurous he provides a few selected references that range from older "classics" by writers such as Ian McTaggart Cowan and Val Geist to recent investigations of the genetic relationships between subspecies of caribou as determined by DNA techniques.

The next section looks at the province's 19 ungulates in more general terms, including their presence or absence of each within each of British Columbia's nine ecoprovinces and 14 biogeoclimatic zones. The inside back cover of the book includes a fold-out colour map of the biogeoclimatic zones. Unfortunately, readers have to discover this for themselves and I did not realize this until well after I had read through this section. The section also very briefly discusses exotic ungulates, a history and general status of management and conservation, and some of the techniques used by biologists to study ungulates in British Columbia. Also provided are a checklist, which includes extinct, non-native, and feral domestic species and subspecies, an identification key, and a key to skulls. The latter is particularly useful for

use in the field when skulls or skull fragments are encountered during a wilderness expedition.

The main portion of the book is devoted to individual accounts for the province's eight native species of ungulates (with 18 subspecies) and one introduced species. Each account gives other common names of the species or subspecies, a description, information on its natural history, range, conservation status, and traditional aboriginal use within the province. The accounts are well written and informative and I particularly like the maps, which show relative density across the province (plentiful, moderate, few, absent) based on information provided by regional wildlife biologists. The descriptions include body measurements (all in millimetres) based on collections within the province. For a book intended for a lay audience, particularly for older readers and those coming from the United States, it would have been beneficial if non-metric measurements had also been provided.

Swallow Summer

By Charles R. Brown. 1998. University of Nebraska Press, Lincoln, Nebraska. 371 pp., illus. U.S.\$16.95.

"This is a book about why I love to do research" are the first words of the preface, and Charles Brown's love and enthusiasm for research permeate the book. For fifteen summers Dr. Brown, with his wife and graduate students, studied Cliff swallows in the area around Cedar Point Biological Station in western Nebraska. The station is close to the Platte River and descriptions of the countryside are glowing. His studies focused on nesting habits, life span and migration patterns, and resulted in the publication of *"Coloniality in the Cliff Swallow: The Effect of Group Size on Social Behavior"*, in 1996 by University of Chicago Press.

Swallow Summer is written in the form of a day-to-day diary for the 1995 summer season, but includes some of the findings from all the years of research in a less academic format than the 1996 book. It gives an insight into the daily highs and lows of field research, the hard slog of routine data gathering, and the dynamics within the team involved in collecting, banding, and recording weights and measurements of up to 900 birds a day. The author describes the daily doings in an interesting way, and readers will look forward to reading about the next day's activities. The Cliff Swallow colonies were almost all found in large culverts and most had been nesting colonies for at least 15 years. Working at the mouths of these culverts to set up mist nets was not pleasant — the stream waters were polluted with farm runoff.

The summer climate in Nebraska produces extreme heat (100-plus deg. F.) and occasional violent wind and thunder storms, all of them potentially dangerous and curtailing bird collection. Bad weather

The book ends with a series of three appendices of scientific names of plants and animals used, estimated numbers of each subspecies of ungulate in the province, and a summary of gestation period, weight at birth, and approximate date-of-birth for 10 species. An excellent glossary, lists of general and specific references, and an index are also provided.

Overall, this is a well researched, well written, and nicely produced book that fulfills its objective. I have no reservations in recommending it for everyone with an interest in the large mammals of western Canada and I will definitely have it along with me on my next visit to British Columbia. This book, along with the five others in the series, are and will be a significant contribution to Canadian mammalogy.

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was a hindrance, but at the end of the season, it was considered successful and knowledge about Cliff Swallow nesting and life histories had advanced. Three graduate students had also learned a great deal — about themselves, about working in a team and just what field research was all about.

Some questions about colony size were not answered that summer. Questions such as why are some colonies smaller than others established in a similar space. Are breeding colonies formed to act only as information centres to communicate news about food sources? Are the "inspection tours" by non-breeding birds in late summer solely for picking out a nesting site for the following year? What is the effect of the parasitic swallow bug on breeding success? Among the discoveries were three colonies in new sites with birds from old colonies; four different birds were seen carrying an egg from one nest to another and a captured swallow had been banded 11 years previously — the highest age recorded for a Cliff Swallow. One half-serious conclusion Dr. Brown draws is a parallel with human "colonies": swallows can be competitive, co-operative, mean, insecure but very social birds.

This is recommended reading for any naturalist, birdwatcher, and in particular for a biology student who might want to find out what field research entails. Judging by his enthusiasm and devotion to Cliff Swallows, Dr. Brown is probably still studying them every summer in Nebraska and taking more first-rate photographs.

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BOTANY

Flora of New Brunswick

By Harold R. Hinds. 2000. Second Edition. Department of Biology, Bag Service #45111, University of New Brunswick, Fredericton, New Brunswick E3B 6E1. 699 pp., illus. \$50.00 + \$8.00 shipping and handling.

This volume is a tremendous jump ahead of the first edition which was published by the author in 1986. In the introductory area is a map of New Brunswick depicting the counties and major rivers, a Foreward by T. G. Dilworth, Acknowledgements, a Glossary with many illustrations, an Introduction, How to use this book, Abbreviations, signs and symbols, Rarity rankings, Common Names (sources), Mi'kmaq and Mailisect names, Chromosome counts, Notes: folklore, toxicity and other information, Specific epithets, History of plant collecting by C. Mary Young (5 pages), and History, physical setting, and regional variation of the flora by S.R. Clayden (39 pages). This contribution by Claden includes information on bedrock assembly, earliest plant life, modernization of the landscape and flora, glaciations and their aftermath, the present environment, ecoregions and their floras, acknowledgements, and references.

The main text starts on page 75 which begins with a Key to Families. This is followed by the Ferns and Fern Allies, Division: Phiophyta (Gymnosperms), Flowering Plants (Dicotyledons), and Flowering Plants (Monocotyledons). All taxa are keyed with numbered unindented keys. The maps and illustrations which could be found with some difficulty at the end of the 1986 volume are now conveniently displayed on either side of the text of most individual species, although rare species are not mapped and some species are lacking an illustration. Text of some species that are of particular interest is high-

lighted. The work is completed by a Bibliography, An Appendix with additions to the Flora of New Brunswick since the publication of the 1986 volume, Exclusions from the Flora of New Brunswick, Plants believed to be Extirpated from New Brunswick, and Plants found in neighbouring provinces/states to Look for in New Brunswick, a Summary of Taxa, Nomenclatural Innovations, and Addenda followed by the index. Also included were four sheets of paper with additional minor corrections dated 19 April 2001.

In the Acknowledgements thanks were given to George Argus (Salicaceae), Jim Goltz (Orchidaceae), Jerrold Davis (Puccinellia), Tony Reznicek (Carex), Don Britton and Dan Brunton (Isoetes), Pierre Taschereau (Atriplex), the late Herb Wagner (Ferns and fern allies), and Arthur Haines and Tom Vining (for permission to rework various taxa from their Flora of Maine). Work for this revised edition was sponsored by the New Brunswick Department of Natural Resources Environmental Trust Fund, the New Brunswick Wildlife Trust Fund, Parks Canada, and several corporations and businesses as well as the commitment to time and labour by many individuals. Hal Hinds worked hard to complete this second edition and fortunately saw it in print before he passed away 9 May 2001.

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Flora of Florida, Volume 1, Pteridophytes and Gymnosperms

By Richard P. Wunderlin and Bruce F. Hansen. 2000. University Press of Florida, Gainesville, Florida. xii + 366 pp., illus. U.S. \$49.95.

This is the first volume of a series of eight that will encompass the flora of Florida: Pteridophytes and Gymnosperms (1), Dicot families (2 to 6) and Monocot families (7 and 8). Because it is the first of the series, in addition to Acknowledgements, there is an Introduction which includes the Historical Background, the Organization of the Flora, and Taxonomic Concepts. This is followed by a description of the Physical Setting (Physiography, Geology, Soils, Climate, and Fire) by Ronald L. Myers (10 pages) and Vegetation of Florida (Upland Communities, Wetland Communities, and Aquatic Communities) by Ronald L. Myers (15 pages), and Botanical Exploration in Florida by

Richard P. Wunderlin, Bruce F. Hansen, and John Beckner (66 pages). All of the above is most useful background information for anyone interested in the vegetation of this state which houses over 4000 taxa.

A key to the Major Vascular Plant Groups: Pteridophytes, Gymnosperms, Dicotyledons, and Monocotyledons can be found on page 100. This is followed by Pteridophytes (Pteridophyta) authored by Nauman, Wunderlin and Bruce F. Hansen (pages 101–300) and Gymnosperms authored by Wunderlin and Hansen (pages 301–328), an Appendix which presents a synopsis of the families (28), total genera (70), species (170), native genera (58), native species (127), endemic genera (0), and endemic species (1), Literature Cited, General Index, Index of Common Names, and Index of Scientific Names.

Throughout this main part of the volume there is a wealth of information: excellent keys, scientific names (with an English translation of the Latin species name), common names, synonymy, publication data for all taxa, detailed descriptions of families, genera and species, habitats, known distribution in the state, overall distribution in North America, and if non-native, where it came from. In addition, interesting and useful comments are found throughout the text and an excellent page drawing is provided for one species of

each genus. Now we can hope that the remaining seven volumes will soon be available for anyone interested in the vegetation of this fortunate state.

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Plant Life Histories: Ecology, Phylogeny and Evolution

Edited by Jonathan Silvertown, Miguel Franco, and John L. Harper. 1997. Cambridge University Press, New York. xviii + 313 pp., illus. U.S. \$29.95.

"Comparative ecology" explores the relationships between species traits and environmental characteristics in order to generate hypotheses and evaluate theoretical expectations regarding the evolution of adaptive traits. Many biologists spend careers determining which traits are correlated with one another, and then trying to decide if correlated traits are the result of common descent or environmental adaptation. But scientists need to beware of the risk of phylogenetic constraints being interpreted as adaptive traits. This book (apparently the proceedings of a Royal Society Symposium) addresses a weakness in this field of comparative biology, in that standard statistical analysis of trait correlations may be compromised because each species is not a truly independent observation. That is, species differ in the degree to which they are phylogenetically related, and hence this limits the inferences possible about ecological adaptation and evolutionary trade-offs.

Chapters are grouped into five sections: phylogenetic perspectives; reproductive traits; seed biology; recruitment and growth; and interspecific interactions. In the book's preface, the editors point out that despite the weaknesses of earlier studies, some correlations and trade-offs in plant life histories seem to be robust across a variety of plant families. For example, plant longevity is negatively correlated with reproductive allocation and seed dormancy, and is positively correlated with outcrossing, genetic diversity, age at first reproduction, and seed mass. Seed mass, in turn, is negatively correlated with seed dormancy, specific leaf area, and relative growth rate, and is positively correlated (at least among herbs) with the presence of vesicular-arbuscular mycorrhizae. Life form (whether a plant is herbaceous or woody) is correlated with leaf chemistry, mating system, and ectomycorrhizae.

Individual chapters highlight particular questions, approaches and findings in plant life history

research. Highlights include Silvertown & Dodd's (Chapter 1) suggestion to limit comparisons to conspecific or confamilial pairs, and Donoghue & Ackerly's (Chapter 2) use of sensitivity analysis to explore the implications of uncertain phylogenies when testing for trait correlations. Crawley et al. (Chapter 3) explore correlates of exotic plant distribution in the British Isles, including phylogenetically controlled independent contrasts of native and alien species traits; they conclude that plants alien to Britain tend to be larger, have larger seeds, are more likely to flower very early or very late in the year, have long-lived seed banks and are more likely to be pollinated by insects than their native counterparts.

Hamrick and Godt (Chapter 6) conclude that genetic diversity and its distribution are more closely associated with individual species' life history traits than with their phylogenetic status; e.g., outcrossing species have less genetic diversity among populations, regardless of their ancestry or other traits. Rees (Chapter 7) concludes that large-seeded plants, long-lived plants, and those with wide lateral spread are less likely to have long-lived seed banks. Westoby et al. (Chapter 8) conclude that larger seed mass does convey benefits in seedling establishment under a wide variety of circumstances, but is correlated with several other plant attributes (including height, growth form, dispersal mode, specific leaf area, and potential growth rate). Chapter 10 (by van Groenendael et al.) explores the relationship between clonality and habitat wetness, noting that a positive correlation disappears when one considers that the majority of aquatic and semi-aquatic species are monocots. Franco and Silvertown (Chapter 11) use three different approaches to confirm that species with high risks of adult mortality tend to reproduce earlier. Sibly (Chapter 12) reviews what is known of life history evolution constrained by trade-offs in heterogeneous environments, confirming that a gradual cline in habitat frequency can still produce an abrupt change in the optimal phenotype. Futuyama and Mitter (Chapter 13) discuss how difficult it is to rigorously evaluate the co-evolution of herbivorous insects and their hosts. Fitter and

Moyersoen (Chapter 14) investigate the history of symbioses in plants, noting that revised classifications suggest a single ancestor for all species supporting nitrogen-fixing symbioses. They also observe that non-mycorrhizal plant species should be considered atypical habitat specialists (typically ruderal or wetland species), having thinner roots, smaller seeds, and habitats with less extreme pH than mycorrhizal species. The final chapter by Goldberg (Chapter 15) confirms that competitive hierarchies between pairs of plant species are consistent, though her analysis (as she acknowledges) did not utilize the methods of independent contrasts employed elsewhere in the book to account for relatedness of species.

Some chapters (4, 5, and 9) were disappointingly jargon-filled, poorly written and edited, or too the-

oretical; this book covers a narrow enough field of interest even without such irritations. I cannot recommend this book for most field biologists or plant ecologists, because of its specialized subject matter. Furthermore, editorial direction and inputs appear to have been minimal and incomplete. But for researchers in the fields of plant population genetics and evolutionary ecology, this volume provides an important synthesis of thinking on a multi-faceted problem being addressed by scientists with a wide range of backgrounds, perspectives, and techniques.

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Flora of Mount Rainier National Park

By David Biek. 2000. Oregon State University Press, Corvallis. vi + 506 pp., illus. U.S. \$29.95.

Mount Rainier National Park which now covers 235 612 acres or 368 square miles lies west of the Cascade Divide and is located in Pierce and Lewis Counties about 55 miles southeast of Seattle in the state of Washington. It was established on 2 March 1899. Much of the park is surrounded by National Forests and Wilderness areas but a good portion of the western border is privately owned and has been clear cut. Mount Rainier which is the highest of the Cascade volcanoes (14 410 feet) occupies about one-third of the area of the park and one-quarter of the park is bare alpine rock, ice, and snowfields. Studies of the plants found in the park began in the late 1900s and C. V. Piper published articles in 1901 and 1902 entitled *The Flora of Mount Rainier* in which 295 species were listed. Since then a number of individuals have increased the knowledge of the flora of the park and published their results.

The introduction to the volume describes the history of the park, how to use the book, a description of how the information in the flora is provided (scientific names, authorities, common names, minimum number of technical terms, habitat and ecological information, where to look for each species, the use of metric units, and abbreviations found throughout the text), how to use the keys, information on plant names (the plant names in this book for genus, species, subspecies, or variety follow J. T. Kartesz (1994: *A Synonymized Checklist of the Vascular Flora of the United States, Canada, and Greenland*), information about the park and its climate. This is followed by information on forests and plant communities, plant geography and distribution, weeds, rare plants, and history.

The 439 pages encompass the keys and descriptions to the major vascular plant groups: Ferns and

Fern Allies, Gymnosperms, Dicots, and Monocots. The families, genera, and species are in alphabetical sequence to make the use of the flora easier for those not acquainted with the relationships in more technical works. Family descriptions and generic descriptions are provided where there are more than one genus or species found in the park. Throughout the text the keys and descriptions of families, genera, and species are not in the technical format normally found in floras but are easy to read and be understood by those who have never taken a botanical course in university but who want to learn something about the vegetation found in this most interesting region. Following the description is useful information on habitat and where to look for a species and other interesting information. Line drawings which were previously published in the *Vascular Plants of the Pacific Northwest* by C. L. Hitchcock are found beside each species (reprinted by permission of University of Washington Press). In addition colour photographs of 64 species on eight pages can be found in the middle of the book.

Following the main text are an appendix of nine pages on which information is provided regarding 79 species which have recently been added to the flora of the park, plus a glossary, a bibliography, and an index of scientific and common names.

The Flora of Mount Rainier National Park by David Biek will be an invaluable help to many of the thousands of individuals who visit the park every year who want to increase their knowledge of the plants of this most interesting region.

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The Flora of Manitoulan Island and the Adjacent Islands of Lake Huron, Georgian Bay and the North Channel, Third Edition

By J. K. Morton and J. M. Venn. 2000. University of Waterloo Biology Series Number Forty. 376 pp. Available from University of Waterloo, Biology Department. Cloth \$40.00 + \$7.50 postage and handling + GST; Coil bound \$27.50 + \$7.50 postage and handling + GST.

The first edition of the flora of this region was published in 1977 by J. K. Morton (University of Waterloo Biology Series Number fifteen, 62 pages). This work included a 12-page introduction, 42 pages listing the flora of 906 species (692 native and 214 alien) with comments, plus literature cited, and indexes to English names, genera, and families.

The second edition was published in 1984 by J. K. Morton and J. M. Venn (University of Waterloo Biology Series Number twenty-eight, 248 pages). This work included a 36-page introduction, 86 pages listing an expanded flora of 1167 species (831 native and 336 alien plus 6 subspecies and 30 hybrids) with frequently expanded comments, plus literature cited, index to scientific names, index to common names, 16 pages with 124 excellent colour photographs, and an index of species found on 53 small adjacent islands. This is followed by 106 pages of distribution maps in the sequence of the text.

The third edition is another great step forward. The introduction is expanded to 46 pages including information on geology, glacial and post glacial history, climate, botanical exploration, vegetation in the various plant communities, conservation, composition and origin of the flora, changes to the flora (15 species appear to have been lost and 72 species, including 32 that are native, have been added since the second edition), statistics of the flora, arrangement of the flora, recording and mapping, rarity and abundance, excluded records, chromosome numbers of plants from the Manitoulin Region, abbreviations and symbols, acknowledgements, and a postscript.

Of particular interest in the above is the following breakdown of the taxa:

	Native	Introduced	Total
Species	861	425	1286
Subspecies	4	4	8
Varieties	9	3	12
Hybrids	34	10	44
	908	442	1350

Of the native taxa, 59 are rare in the Manitoulin Region although most are common in other parts of Ontario or in neighbouring parts of the continent. The area, which covers about 2800 sq. km. (about 1090 square miles), contains about a third of the flora of Canada although it occupies only 0.028% of the country. It is thus, without question, one of the most interesting areas in our country.

In the flora section, which now numbers 106 pages, in addition to the new taxa, many of the taxa have additional information which will be most interesting to the reader. This, like the second edition is followed by the bibliography, index to scientific and common names, the list of illustrations, the 124 colour photographs, the floras of the smaller islands, and distribution maps.

This publication will be invaluable to anyone interested in the flora of Ontario and the authors are to be congratulated for the result of their continuing study of the region.

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ENVIRONMENT

Food Webs and Container Habitats: The Natural History and Ecology of Phytotelmata

By R. L. Kitching. 2000. Cambridge University Press, New York. xiii + 431 pp., illus. U.S. \$100.

To most Canadians, a pitcher plant (*Sarracenia* sp.) is unique because it is one of very few carnivorous plants. However, it is the life that thrives, not that which perishes, in these pitchers (and other water-filled plant cavities) that is the topic of this very thorough book. The over 100 years of research on phytotelmata (food webs in plant containers) is covered quite thoroughly. The author himself has been involved in this research for over 30 years,

starting with his post-graduate work at Oxford. Studying most food webs in nature is very complex, there are no isolated food webs, though container habitats come close, and offer ecologists small, relatively simple systems to study.

The information in this book is of the weird and wonderful sort that makes birders, plant enthusiasts, herpetophiles, and really all naturalists exclaim, "wow!" However, this work is not a coffee table book, nor is it targeted at the average naturalist (whatever that may be!). The book is a summary of

many people's research, and is directed towards ecologists and entomologists, though researchers of other phytotelm taxa will be interested as well.

The book is organized into five parts, with the first one giving a description of the major types of container habitats (tree holes, bromeliads, etc.) and the ecological niches of the inhabitants (saprophages to predators); it is this section that will be most consumable by naturalists. The book culminates in an annex entitled "The Bestiary" which outlines the animals known to make use of phytotelmata, from vertebrates to flatworms, though by far the majority of this section is devoted to the animals that dominate the world as a whole, the insects. The Bestiary is a straightforward systematic breakdown of the animals, with very useful tables which direct the reader to published works of each taxon.

The bulk of the book compares phytotelmata on many scales, from local to global, across time and habitats. The organisms from different areas and different types of cavities are thoroughly described; the relationships among these phytotelm are explained

quite well. It is these sections that draw most heavily on the primary literature.

The bad points? There are too few photographs, and those that are there are all dark. Almost all of the graphs and line drawings are pixelated. Pixelated! For hundreds of years, publishers have been able to make a straight line look like a straight line, and in this era of technology there is absolutely no excuse for such inferior quality, especially from such a fine publisher. The book is directed primarily at biologists, and as such it is understandable that the binomial names of organisms are used; using common names occasionally (when such exist), or at least parenthetically, would colour the writing with a favourable hue for the non-specialist.

Overall though, this is a well-written book on a subject that certainly deserves the attention.

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The Friendship of Nature, A New England Chronicle of Birds and Flowers

By Mabel Osgood Wright. Edited by Daniel J. Philippon. 1999. John Hopkins University Press, Baltimore. 172 pp., illus. Reissue of 1900 book. U.S. \$16.95.

Every so often a book comes along which revives a figure of the past. That is the case with *The Friendship of Nature*, written by Mabel Osgood Wright, founder of the Connecticut Audubon Society, author of 25 works of fiction and non-fiction, long-time associate editor of *Bird-Lore* magazine (now *Audubon*), accomplished photographer, and the organizing force behind one of the first privately owned bird sanctuaries in the United States. As editor Dan Philippon (University of Minnesota, Twin Cities) writes in his lengthy but excellent introduction, Osgood Wright is "not only a neglected writer and illustrator but also a lost hero of the conservation movement".

The introduction provides intriguing background to this remarkable woman, who realized the need to integrate the personal and the regional, to extend herself through contact with nature. *The Friendship of Nature*, roughly organized according to the seasons, paints a loving portrait of the birds and flora Osgood Wright encourages and tends in her large garden, and the wildlife and seasonal transformations she experiences in the surrounding countryside.

Her keen observations and insights, expressed in meticulous prose and poetic descriptions typical of the period (1894), are a delight to read. I particularly like her charming, and wholly accurate,

sketches of the bobolink: "in the tufts of grass out in the open, hovering above a nest that is merely a heap of twigs, the bobolink calls in a perfect ecstasy: 'Bobolink o'wadolink, winterseeble-see me-see me-see!'" (springtime), and "madcap bobolinks are now anxious to disperse their broods before the mowers lay bare their shabby nests; and half bewitched, they sing, and pausing, float with outstretched wings, then soaring, pour out torrents of high notes" (summer).

But it isn't all pretty pictures and words. Osgood Wright also makes astute observations regarding institutions such as agriculture: "If you serve Nature, waiting her moods, taking what she yields unforced, giving her a love devoid of greed, she will be a regal mistress, and all she has to bestow will be yours. Exact and say to one little field: 'This year you shall yield this crop or that,' and it becomes a battleground, where Nature, well equipped, wages war with man."

The Friendship of Nature would make an excellent gift for naturalists, birders, and gardeners who love books. Not too long, divided into 11 neat and clearly written chapters, and illustrated with Osgood Wright's own photographs, it is a quick and gratifying read.

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Earth Future: Stories from a Sustainable World

By Guy Dauncey. 1999. New Society Publishers, Gabriola Island. xii + 161 pp. \$17.95.

In this day and age when the world's population is bombarded with negativity regarding the earth's future, the positive potential often appears lost. Guy Dauncey author, speaker, organizer, and consultant on post-industrial environmentally sustainable future provides some possible scenarios. In his short works of fiction he attempts to offer an environmentally sustainable positive vision. The majority of the initiatives he notes are already happening.

The 21 short stories, two poems and one pledge tell not of the completion but of the making of a vision. Subjects covered include the expected recycling, organic gardening, co-operatives, nature of consciousness, de-globalization to name a few. Most stories have concluding notes with lists provided of

contacts, many being internet URL's. Dauncey does not aim to provide a balanced view. His intent is rather to provide a look at a positive possible future. There is recurring anti-hitech theme with a strong emphasis on low tech solutions.

If one is looking for positive infusion for a possible future, this book provides it. The book also has the potential, I feel, as a discussion starter. Guy Dauncey provides all in all not a bad read, with a strong emphasis on the positive future, which requires us all to create our positive visions of the future.

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Vanishing Borders: Protecting the Planet in the Age of Globalization

By Hilary French. 2000. W.W. Norton & Company Ltd., London. 257 pp., illus. U.S. \$13.95; Pdf version 2 downloads at U.S. \$5.50 each.

In today's modern world with increased rapidity of communication and travel, borders no longer limit potential dangers of the outside world's impact on a nation's environmental resources. Hilary French provides, in this Worldwatch publication, an overview of the threats as well as potential cures to the problems of globalization.

The reader becomes acquainted with the issues in the first section of the book entitled "The Ecology of Globalization." In this section chapters with its descriptive titles; "Nature Under Siege," "the Biotic Mixing Bowl," "Global Grocers," "the Export of Hazard", and "Sharing the Air"; one is provided with an array of facts and analyses describing the plight of the world's resources. Issues encountered included under funding, shortcomings of present economics, unsustainable agricultural progress, bioinvasions to name a few.

In the second section of the book, "Reforming Global Governance" policy problems and potential solutions are offered. Once again the reader is provided insight into the chapter contents via chapter entitled; "Trade Wars", "Greening the Financial Architecture", "Strengthening Global Environmental

Governance", and "Partnerships for the Planet." As the titles suggest impact of present globalization policies, and present economic theory are discussed in relation to their environmental impact.

Overall, Hilary French has provided a book with a great deal of information summarized from a large number of sources in a fashion which will be familiar to those who are familiar with the World Watch Institute. A great deal of the referenced material originates in reports normally not available to the common reader. The summarization of the present day data continues to indicate a gloomy future for the world community as do many other publications on the future. The outlining of solutions makes this book somewhat unique.

The book is meant for the general reader to provide information to be used in the decision making process at all levels, personal or international. The material has been provided in a well organized and readable fashion. For those with an interest and stake in the future this will provide a good read and reference.

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Pandora's Poison: Chlorine, Health, and a New Environmental Strategy

Joe Thornton. 1999. MIT Press, Cambridge, Massachusetts. 597 pp., illus. U.S.\$34.95.

This is a thick, formidable book. It presents a compelling, seemingly irrefutable position: that production, use, and disposal of chlorine gas and its chemicals, a phenomenon of the past century, is bad for us, bad for society, and bad for the environment. The author has achieved his aim of a readable essay, while his figures, tables, appendices, and about a thousand references, offer detailed documentation.

Chlorine itself is an effective bleach and a disinfectant. Chlorine gas does not occur naturally, but industry now produces 40 million tons of it annually. This man-made gas is the feedstock for 11 000 organochlorine compounds including plastics, pesticides, and solvents. Chlorination decreases a chemical's stability, making it more reactive, and usually more toxic. And while some of these pollutants may degrade in less than a year in the temperate climates in which they are produced, they may last for centuries near the frigid poles, which become the ultimate global sinks. Organochlorines are now "ubiquitous on a global scale."

Sadly, scientists assigned to investigate the degree of toxicity of the commonest chlorine compounds have followed the Risk Paradigm. They tend to calculate only the Lowest Observed Adverse Effect Level (LOAEL), or the No Observed Adverse Effect Level (NOAEL). Each chemical is studied separately. Yet, any exposure to any organic chlorine compound carries some risk of mutations, of cancer, of endocrine disruption (including infertility), of neurotoxicity, and of sub-clinical effects, among others.

Thornton, in striking contrast to industry, advocates the Ecological Paradigm, because, as Canadian ecologist Glen A. Fox has pointed out, "health damage occurs on a continuum." The Ecological Paradigm, a holistic approach, views all organochlorines as "end products unified by a single history, a common economic dynamic, and a single root material." There is no safe dose. A central tenet is the precautionary principle. For this, the first rule is Reverse Onus, which means erring on the side of caution. The second is Zero Discharge and the third is Clean Production.

What dangers are known? Prostate cancer, non-Hodgkin's lymphoma, and multiple myeloma have tripled in prevalence between 1950 and 1994 in the United States, and cancers of the testis, kidney, thyroid, and liver have doubled. Perchloroethylene, used in dry-cleaning, causes leukemia in the laboratory, and trichloroethylene causes kidney cancer. The rate of non-Hodgkin's lymphoma in domestic dogs doubles when the owner applies 2,4-D on the lawn four times during the summer. Dioxin deposition in Great Lakes sediments has increased 2000-fold since 1940. Thousands of animals died near Seveso, Italy, when chlorophenols and dioxins escaped from a factory manufacturing trichlorophenols.

What can be done? The first principle of public health practice must be prevention. The ever-increasing production of dangerous chlorine products must be checked; PVC or vinyl plastic is now the largest user of chlorine in the world. Phasing out chlorine represents a "major step on the road toward a sustainable economy based on clean materials and production techniques." When a new pulp and paper plant is to be built, totally chlorine-free bleaching methods (TCF) allow less expensive construction. Major companies have eliminated the use of chlorinated solvents and some have switched to propane, isobutane, and ammonia as refrigerants. In dry-cleaning, chlorine should be replaced with 'wet cleaning' as some establishments have already done. Plastics can be made from polypropylene rather than PVC (vinyl). Ozonation is preferred to chlorine in swimming pools. Sometimes the substitutes cost less, sometimes more, but jobs need not be lost. Thornton explains the political and social barriers and the details of the economic costs and benefits of each intervention. The environment is at stake.

Industry opened Pandora's box less than a century ago. Now it is time to shut it.

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NEW TITLES

Zoology

- Animal behavior desk reference.** 2001. By E. M. Barrows. 2nd edition. CRC Press, Boca Raton, Florida. 936 pp. U.S. \$129.95.
- ***Bats of Papua New Guinea.** 1998. By F.J. Bonaccorso. Conservation International (distributed by University of Chicago Press, Chicago). 492 pp., illus. U.S. \$40.
- Bears of the world.** 2000. By L. Craighead. Voyager, Stillwater, Minnesota. 132 pp., illus. U.S. \$29.95.
- Biology of marine birds.** 2001. Edited by E. A. Schrieber and J. Burger. CRC Press, Boca Raton, Florida. 744 pp. U.S. \$79.95.
- ***Birds of Delaware.** 2000. By G. K. Hess, R. L. West, M. V. Barnhill III, and L. M. Flemming. University of Pittsburgh Press, Pittsburgh. xv + 635 pp., illus. U.S. \$65.
- ***Birds of southern South America and Antarctica.** 2001. By M. R. de la Pena and M. Rumball. Originally published by Collins in 1998. Princeton University Press, Princeton. 304 pp., illus. U.S. \$24.95.
- Canadian feathers: a loon-atics guide to anting, mimicry, and dump nesting.** 2001. by P. E. Bumstead. Simply Wild Publications, Calgary. \$29.99.
- Carnivore conservation.** 2001. Edited by J. L. Gittleman, S. M. Funk, D. Macdonald, and R. K. Wayne. Cambridge University Press, New York. xiii + 675 pp., illus. Cloth U.S. \$130; paper U.S. \$49.95.
- ***Cetacean societies: field studies of dolphins and whales.** 2000. Edited by J. Mann, R. C. Connor, P. L. Tyack, and H. Whitehead. University of Chicago Press, Chicago. xiv + 433 pp., illus. Cloth U.S. \$85; paper U.S. \$35.
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- Neotropical tree boas: natural history of the *Corallus hortulanus* complex.** 2001. By R. W. Henderson. Krieger Publishing, Melbourne, Florida. Illus.
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- †**Owls aren't wise and bats aren't blind: a naturalist debunks our favorite fallacies about wildlife.** 2000. By W. Shedd. Three Rivers Press (Canadian distributor Random House, Mississauga). ix + 322 pp., illus. \$21.
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- Human dimensions of wildlife management in North America.** 2001. Edited by D. J. Decker, T. L. Brown, and W. F. Siemer. The Wildlife Society, Bethesda, Maryland. 464 pp. cU.S. \$40.
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- A whale biologist at work.** 2001. By S. B. Collard, III. Watts, Danbury, Connecticut. 48 pp., illus. Cloth U.S. \$22.50; paper U.S. \$6.95.

Wolf: spirit of the wild: a celebration of wolves in word and image. 2000. Edited by D. Landau. Sterling, New York. xi + 182 pp., illus. U.S. \$24.95.

The world of frogs, toads, salamanders, and newts. 2000. Edited by R. Hofrichter. Firefly, Willowdale, Ontario. 264 pp., illus. U.S. \$49.95.

***The world of humming birds.** 2001. By R. Burton. Firefly Books, Willowdale, Ontario. 158 pp., illus. \$40.

Botany

***The ecology of trees in the tropical rain forest.** 2001. By I. M. Turner. Cambridge University Press, New York. xiv + 298 pp., illus. U.S. \$80.

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***Guide to standard floras of the world.** 2001. By D. G. Frodin. 2nd edition. Cambridge University Press, New York. xxiv + 1100 pp., U.S. \$240.

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†**Vegetation and the terrestrial carbon cycle; modelling the first 400 million years.** 2001. By D. I. Beering and F. I. Woodward. Cambridge University Press, New York. x + 405 pp., illus. U.S. \$150.

Environment

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Biological diversity: balancing interests through adaptive collaborative management. 2001. By L. E. Buck, C. C. Geisler, J. Schelhas, and E. Wollenberg. CRC Press, Boca Raton, Florida. 504 pp. U.S. \$49.95.

Biogeography of the West Indies: patterns and perspectives. 2001. Edited by C. A. Woods and F. Sergile. 2nd edition. CRC Press, Boca Raton, Florida. 608 pp., U.S. \$139.95.

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***Bringing the biosphere home, learning to perceive global environmental change.** 2001. By M. Thomashow.

MIT Press, Cambridge, Massachusetts. xi + 244 pp., U.S. \$27.95.

The earth's biosphere. 2002. By V. Smil. MIT Press, Cambridge. 360 pp., illus. U.S. \$32.95.

†**Elements of mathematical ecology.** 2001. By M. Kot. Cambridge University Press, New York. 453 pp., illus. Cloth U.S. \$110; paper U.S. \$39.95.

Environmental careers, environmental employment, and environmental training. 2001. Edited by W. L. Filho. Peter Lang Scientific Publishers, New York. U.S. \$31.95.

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†**Flammable Australia: The fire regimes and biodiversity of a continent.** 2002. Edited by R. A. Bradstock, J. E. Williams, and A. M. Gill. Cambridge University Press, New York. ix + 462 pp., illus. U.S. \$130.

†**Fungal conservation: issues and solutions.** 2001. Edited by D. Moore, M. M. Nauta, S. E. Evans, and M. Rotheroe. Cambridge University Press, New York. x + 262 pp., illus.

†**Globalization and environmental reform.** 2001. By A. P. J. Mol. MIT Press, Cambridge, Massachusetts. x + 273 pp., illus. U.S. \$37.95.

Hands on nature. 2000. Edited by J. Lingelbach and L. Purcell. Vermont Institute of Natural Science, Woodstock. 329 pp., illus. U.S. \$24.95.

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Insects and gardens: in pursuit of a garden ecology. 2001. By E. Grissell. Timber Press, Portland, Oregon. 348 pp., illus. U.S. \$29.95.

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†**Norms of nature.** 2001. By P. S. Davies. MIT Press, Cambridge, Massachusetts. xiv + 234 pp.

†**Political nature: environmentalism and the interpretation of western thought.** 2001. By J. M. Meyer. MIT Press, Cambridge, Massachusetts. xii + 210 pp.

Reefscape: reflections on the Great Barrier Reef. 2001. By R. Love. Joseph Henry Press, Washington. 250 pp. U.S. \$24.95.

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†**Solutions for an environment in peril.** 2001. Edited by A. B. Wolbarst. Johns Hopkins University Press, Baltimore. xv + 214 pp. U.S. \$22.50.

Spatial processes and management of marine populations. 2001. Edited by G. H. Kruse, N. Bez, A. Booth, M. W. Dorn, S. Hills, R. N. Lipcius, D. Pelletier, C. Roy, S. J. Smith, and D. Withrell. Alaska Sea Grant College Program, Fairbanks. 730 pp. U.S. \$40 in Canada and U.S.A.; U.S. \$60 elsewhere.

***Thoreau's country: journey through a transformed landscape.** 2001. By D. Foster. Harvard University Press, Cambridge, Massachusetts. 270 pp., illus. U.S. \$16.

World resources 2000 – 2001 people and ecosystems: the fraying web of life. 2000. By World Resources Institute, Washington. ix + 389 pp., illus. Cloth U.S. \$49; paper U.S. \$27.95.

Miscellaneous

†**Backcountry huts and lodges of the Rockies and Columbias.** 2001. By J. Scott. Johnson Gorman, Calgary. 287 pp., illus. \$24.95.

***Cheltenham in Antarctic: the life of Edward Wilson.** 2001. By D. M. Wilson and D. B. Elder. Reardon Publishing, Leckhampton, England. 144 pp., illus. £ 9.99.

†**Minutes of meetings, 1961 to 1969 of the McIlwraith Ornithological Club, London, Ontario, Canada.** 2002. By W. W. Judd. Phelps Publishing, London. iii + 168 pp. \$10.

†**Rediscovering the Great Plains: journeys by dog, canoe, and horse.** 2001. By N. Henderson. Johns Hopkins University Press, Baltimore. Xv + 214 pp., illus. U.S. \$29.95.

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Understanding soil change. 2001. By D. D. Richter, Jr. and D. Markewitz. Cambridge University Press, New York. xiv + 255 pp., illus. U.S. \$69.95.

Books for Young Naturalists

Bears. 2001. By D. Fertl, M. Reddy, and E.D. Stoops. Sterling, New York. 80 pp., illus. U.S. \$17.95

Eagles of Devil Mountain. 2001. By M. J. Rauzon. Danbury, Watts, Connecticut. 48 pp., illus. Cloth U.S. \$22.50; paper U.S. \$6.95.

Fireflies. 2001. By S. Walker. Lerner, Minneapolis. 48 pp., illus. U.S. \$22.60.

Mountain gorillas. 2001. By K. Kane. Lerner, Minneapolis. 48 pp., illus. U.S. \$21.95.

Oceans. 2001. By S. H. Gray. Compass Point Books, Minneapolis. 48 pp., illus. U.S. \$15.95.

Songbirds: the language of song. 2001. By S. A. Johnson. Carolrhoda, Minneapolis. 48 pp., illus. U.S. \$23.95.

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*assigned for review

The Ottawa Field-Naturalists' Club Awards April 2001

Each year, The Ottawa Field-Naturalists' Club makes a number of awards to certain members and some non-members who have distinguished themselves by accomplishments in the field of natural history and conservation, or by extraordinary activity within the Club. The following citations, in an abbreviated form, were read at the Club's annual soirée held, as usual, at the Unitarian Church of Ottawa.

HONORARY MEMBERSHIP: DONALD M. BRITTON

Donald M. Britton is one of Canada's most distinguished and accomplished botanists. He is recognized worldwide as an authority on fern taxonomy and systematics with more than 50 years of contributions to understanding the taxonomy and evolution of major groups including *Dryopteris*, *Polypodium*, *Woodsia*, *Polystichum*, *Isoetes*, and *Lycopodium*. He has been a leader in the use of cytological techniques in his studies, as well as more traditional approaches such as morphological, anatomical, developmental, and phytogeographic analyses, thereby helping to define *biosystematics* most appropriately.

Dr. Britton was born in Toronto and received his bachelor's degree from the U of T. His doctoral work was done at the University of Virginia, where he received his Ph.D. in 1950. Although he did his early work on the Boraginaceae (which includes viper's bugloss and forget-me-nots) and the genus *Rubus* (blackberries), he gradually turned almost all of his attention to the ferns and fern-allies. After a few years in the Horticulture Department at the University of Maryland, Dr. Britton returned to Canada in 1958 to take up a position in the Botany and Genetics Department at the University of Guelph, where he remained until his retirement, and where he continues to devote time to botanical studies. His activities in Guelph included continuous involvement in the Guelph Field-Naturalists' Club, where he served for many years as Chairman of their Conservation Committee and led many field trips.

Dr. Britton has been a prolific author (including co-authoring *Ferns of Canada* with William Cody). His involvement with the Flora North America project includes serving as regional reviewer for pteridophytes of eastern Canada as well as being an author of the treatment of *Isoetes*. He has described numerous taxa new to science, including two quillworts from the Ottawa Valley. He is an exceptional field botanist with a careful and thorough approach to all his research, assuring the lasting value and reliability of his observations.

Dr. Britton is an exceptionally generous scholar who has inspired professionals and amateurs alike across North America and Europe. Those lucky enough to have worked with him have been touched by his warmth, humour, and especially his equal accessibility to students, amateurs and scholars.

In 1991, the Canadian Botanical Association presented Dr. Britton with its premier achievement award, the Lawson Medal, for *outstanding scientific achievement over the period of a career*. It is now our turn to honour him by welcoming Dr. Britton as an Honorary Member of the Ottawa Field-Naturalists' Club.

HONORARY MEMBERSHIP: JOHN (JACK) GILLET

John Montague Gillett, better known to his friends and colleagues as "Jack," is one of the Ottawa Field-Naturalists' Club's most distinguished members. His career as a respected Canadian plant taxonomist, and his activities in the Club make him a most fitting recipient of Honorary Membership.

Jack is a native Ottawan. After serving in the Royal Canadian Air Force during World War II, he returned to Canada and earned his B.A. from Queen's University and Ph.D. at Washington University in St. Louis. In 1949, Jack began his botanical career in the herbarium at the Department of Agriculture and participated in many expeditions. He left the Plant Research Institute in 1972, to become curator of the herbarium at the National Museum of Natural Sciences [Canadian Museum of Nature]. Here he continued work on a flora of Gatineau Park and taxonomy of many plant groups, especially clovers (the genus *Trifolium*). He retired from the Museum in 1983.

His work on Canadian botany includes monographs on *Hypericum*, *Polygala*, *Bartonia-Obolaria*, *Gentianella-Gentiana*, *Trifolium*, and others. Floristic works include studies of the Mealy Mountains in southern Labrador, the Madoc region of Ontario, the St. Lawrence Seaway and the Ottawa District. In the course of his career, he has described several new species of plants from Canada, not an insignificant thing in the second half of the 20th century.

Many of Jack's papers have been of great importance to plant taxonomy in North America. Among these are his papers on the economically important genera *Agropyron* and *Trifolium*. In recent years he has made a series of wonderful contributions to *Trail & Landscape* on the plants of the Ottawa district. These articles are useful identification aids backed by careful taxonomic evaluations and judgement, not merely lists of plants. They are of use to amateur and professional alike. His *Index to the Transactions of the Ottawa Field-Naturalists' Club* and the Ottawa Naturalist was a tedious task, but a remarkable labour of great benefit. His *Checklist of the Vascular Plants of the Ottawa-Hull Region*, written with David White, is an indispensable tool for anyone working with the plants of the region.

Jack has a long history of activity in the Club. From 1958 to 1970 he served on the Council. From 1959 to 1961 he served in the arduous post of Treasurer, and for several years in the 1960s, he was Auditor. From 1966 to 1970 he served as Chair of the Publications Committee. As well as these administrative tasks Jack has also been prominent in Club activities with his many contributions to *Trail & Landscape* (16 papers and counting) and has been leading field trips and giving talks for more than half a century.

In recognition of Jack Gillett's outstanding botanical achievements and his considerable service to the OFNC, the Club is pleased to award him an Honorary Membership.

HONORARY MEMBERSHIP: E. FRANKLIN POPE

In the long history of the Ottawa Field-Naturalists' Club, few people can match the years of steady dedicated commitment that Frank Pope has devoted to this organization. For the past twenty-two years, he has served continuously on Council in various capacities and has been active in

many committees. In 1980 he served on the Executive as Corresponding Secretary, followed by three years as Recording Secretary. He was elected Club President in 1984, and again in 1985, a period when the Club was deeply involved in environmental advocacy, taking a courageous and public stand on what was then a controversial viewpoint.

For five years, 1988 to 1991, he served as Chairman of the Finance Committee. In 1992, he was again elected President, a position which he held for the next four years. During this second term as President, he had the added responsibilities of overseeing all the numerous arrangements associated with the 1993 conference of the Federation of Ontario Naturalists, which was hosted by the OFNC. Always ready to offer his services where needed, in 1999 he took over the vacant position of Club Treasurer, which he filled again in the year 2000. An impressive record of service!

Repeatedly over the years, Frank has assumed responsibilities that made heavy demands on his time and energies. Most notable of these undertakings was his unflagging leadership in the effort to gain environmental protection for Alfred Bog. In this long drawn-out struggle, Frank's commitment never wavered in the face of setbacks. A large section of Alfred Bog is now safe from commercial development due, in large part, to Frank's steadfast leadership.

Over a period of many years, Frank has been an ever-present strength on Council, adding his thoughtful and experienced contributions to deliberations. His long presence on Council has provided the Club with important continuity. In recognition of his years of remarkable and dedicated service, the Ottawa Field-Naturalists' Club is pleased to confer Honorary Membership on E. Franklin Pope.

HONORARY MEMBERSHIP: JOYCE and ALLAN REDDOCH

Joyce and Allan Reddoch have been club members since 1967. Both have served on Council and on various committees, performing outstanding service on the conservation committee. They have contributed greatly both to the running of the club and to its natural history goals. They have added significantly to the knowledge of Canadian natural history, with particular emphasis on the Ottawa area. Their fame as orchid experts extends far beyond the boundaries of the Ottawa region.

Joyce's ten-year tenure as editor for *Trail & Landscape* has been a monumental contribution to the Ottawa Field-Naturalists' Club. The attention to quality and detail that she brought to this demanding position ensured that the high standards set by the founding editor were maintained.

The years of work that Allan and Joyce have spent on conservation issues, preparing reports, attending meetings, and hounding bureaucrats and politicians, demonstrate a dedicated labour seldom matched. The Club was always assured that, with the Reddachs representing us, our position would be presented with a measure of excellence and integrity that we could be proud of.

Joyce and Allan's work on orchids has been and is greatly valued by naturalists and professionals alike. They have published papers on their work in both popular and scientific venues culminating in the authoritative and thorough treatment of the orchids of the Ottawa District in *The Canadian Field-Naturalist* 111(1): 184 pages as a special issue in 1997.

Over the years, Allan and Joyce have always operated as

a team, and as it is impossible to separate the activities of one from the other the logical decision was to give them a joint award. It is our pleasure to add Joyce and Allan Reddoch to our roster of Honorary Members.

CONSERVATION AWARD — MEMBER: ALBERT DUGAL

The cause of natural history conservation in the Ottawa area has been well served by OFNC members over the years. However, the road to habitat protection does not run smoothly and it takes individuals with a high degree of diligence and dedication to keep working on issues over the long term. Albert Dugal is one such individual.

Most club members will be familiar with Albert's long association with the Leitrim Wetlands. For over 20 years Albert has been working hard to save this ecologically significant area. His inventory (still ongoing) of Leitrim's vascular plants has thus far recorded an astonishing 500 species. Encouraged by Albert, local naturalists have recorded impressive lists of other organisms in the wetland complex.

Albert has written extensively about the Leitrim Wetlands (see *Trail & Landscape* 24(2), 26(3) and 27(4)) providing in-depth information about a once little-known area. Whenever it seems that the issue has moved to the back of people's consciousness, Albert returns with new information. In the last couple of years he has redoubled his efforts in the fight to save the remaining Leitrim wetlands from development. Working with the OFNC Conservation Committee as well as members of the Sierra Club, Albert has attended meetings, written letters, prepared briefs and given talks about the Leitrim site, raising people's awareness of the issue and encouraging them to join with his efforts for preserving this area forever.

Albert also continues working for protection for the former South Gloucester Conservation Area, adding new species to his plant inventory, leading interested parties into the area, and providing expertise and background information for the Conservation Committee to aid in the committee's efforts. As well, he was a vital member of the Environmental Health Advisory Group (EHAG) under the Regional Municipality of Ottawa-Carleton. Albert has also acted as the Club's liaison with other groups such as the Goulbourn Environmental Advisory Committee, where his botanical expertise was instrumental in persuading Goulbourn Council to reject the residential subdivision plan for Westridge Phase III which encroached upon the Poole Creek Wetland. He also triggered the review which restored provincially significant status to the Fernbank Wetland.

When the OFNC established the Conservation Award in 1981 to recognize outstanding contributions to natural history preservation in the Ottawa area, Albert Dugal was the first recipient. At that time his efforts in gaining protection for the Shaw Woods (successful) and for the South Gloucester Conservation Area (ongoing), as well as for his work in bringing attention to the unique natural values of Petrie Island were recognized. In 1991 Albert again won the Conservation Award, this time for his unstinting and persistent work on seeking protection for the Leitrim Wetlands.

For the year 2000 Conservation Award for Members, we are delighted that once again, Albert Dugal is the recipient. His perseverance and tenacity over many, many years in working for the protection of our precious natural heritage, particularly the Leitrim Wetlands, is without doubt impressive. Albert Dugal is more than worthy of this award.

CONSERVATION AWARD — NONMEMBERS: DAVID MILLER

From time to time, it is necessary to recognize outstanding contributions to the cause of natural history conservation in the Ottawa Valley by outside governmental or non-governmental organizations, or individuals working within these organizations, and therefore not directly associated with the Ottawa Field-Naturalists' Club. As originally conceived in 1992, the award for such organizations and individuals was made only to non-members. We are making an exception in this case because, although David Miller has been a member of the Club since 1993, he has made his most significant contributions to conservation through his involvement with the Regional Municipality.

For those who have worked on conservation concerns in the Ottawa area over the last decade, the name David Miller is a familiar one. David is an environmental planner, formerly with the Regional Municipality of Ottawa-Carleton, now with the new city of Ottawa, and one of the more visible faces in the planning department. David is particularly skilful at translating ecological information and its implications into a form easily understood by bureaucrats and politicians. One recent example of this was his role in the acquisition of a significant portion of the South March Highlands, identified as a critical area both Provincially and Regionally. Because he was able to effectively demonstrate the tremendous conservation opportunity this presented, the powers-that-be acted quickly. The end result has been the largest single purchase of conservation lands in the region since at least the 1960s. Public approval for this decision was overwhelmingly positive.

Many club members will recall the Region's Natural Environment Systems Strategy (NESS) project of the mid to late 1990's which identified environmentally significant areas within the district. David's participation in site investigations and supervision of this project was vital in ensuring that it received the appropriate attention and consideration.

One of David's most important qualities is his ability to listen to and understand the various positions on environmental issues. Representation of natural areas in the latest Regional Official Plan was substantially increased over previous versions, almost certainly due to David's ability to present sound ecological concepts in such a way that they could be integrated within the planning process.

David was also instrumental in setting up a Working Group to look at the feasibility of establishing a community based land trust organization, and to provide a forum to discuss opportunities or partnership proposals prior to more formal land trust activities. The OFNC has been represented on this committee from the beginning. Other local conservation issues that have benefited from David's participation include the regional Wildlife Protocol and protection of Petrie Islands. It is therefore our pleasure to give to David Miller the club's year 2000 Conservation Award for non-members.

GEORGE MCGEE SERVICE AWARD: PHILIP MARTIN

In organizations such as the Ottawa Field-Naturalists' Club, run entirely by volunteers for the benefit of all members, there are always certain individuals who stand out by virtue of their special contribution of time and effort. The George McGee Service Award is given in recognition of the efforts of these individuals. This year, we are pleased to make that award to Philip Martin.

Philip joined the OFNC in 1982 shortly after arriving in Ottawa and soon became an active participant in club affairs. Philip has been regularly leading walks since 1983. For many years, he led the spring flower walk in May, an astronomy outing in late August or early September, and a general autumn walk in Gatineau Park in early November. During the past few years, the number of walks in which he has participated as a leader has risen, and last year, he was involved in seven dealing with animals, shrubs, flowers, water plants, and even stars. Philip is always anxious to share his knowledge of plants and fungi with others, and his warm, genial manner has made him a favourite field trip leader. His interest in excursions led to his chairing the Excursions and Lectures Committee not once, but twice, from 1984-1986 and from 1997-2000.

Upon leaving his post as Chair of the E&L Committee, Philip volunteered his time to the Conservation Committee, where he now a major player in the Club's effort to save the Leitrim wetlands.

Those of you who come out to these soirées know that Philip has been one of the organizers of the event and has overseen the photography and art exhibits for a number of years.

Philip Martin is clearly a most fitting recipient of this year's George McGee Service Award.

ANNE HANES NATURAL HISTORY AWARD: ROBERT E. LEE

Robert E. Lee has been a member of the Ottawa Field-Naturalists' Club since 1981, having come up through the ranks of the Macoun Field Club, where his leadership continues today to be an outstanding contribution to the naturalist community.

Over the years he has built up an impressive store of knowledge of the natural history of the Ottawa District, much of it gained through independent investigation on his part.

Rob possesses that combination of attributes that best exemplify a top-rate naturalist: a lively curiosity concerning the world of nature, the patience for careful observation and meticulous recording, and the tenacity to see a project through to its successful conclusion. He has demonstrated a fine talent for independent research, using imagination, resourcefulness and ingenuity to obtain and record biological data.

His recent study of leopard frogs culminated in an excellent article published in *Trail & Landscape*. In this study, Rob produced new and hitherto unpublished information about the habits and movements of leopard frogs.

Curious as to how many leopard frogs were summering on his land, Rob devised a method to distinguish one individual from another. Keen observation led him to the conclusion that, as in fingerprints, no two frog patterns were precisely identical. From this basis, and working with the patterns of 175 different frogs, he cleverly devised a classification system, with a key which permitted quick identification of individuals. Armed with this identification tool, he was able to follow the activities of individual frogs, and thus to document behaviour and migration patterns. His observations will surely lead to further research on these amphibians.

Anne Hanes, the founding editor of *Trail & Landscape*, would be deeply satisfied with this well-conducted investigation by an amateur naturalist. His fellow naturalists are pleased to honour Robert E. Lee with the coveted Anne Hanes Natural History Award.

MEMBER OF THE YEAR, 2000: SANDRA GARLAND

Our club has a long history of fulfilling our goal of disseminating information relating to natural history through traditional means such as public lectures and print media. In recent times we have taken advantage of newly-developed electronic technologies to enhance our activities in this respect.

In 1996, a notice posted in *Trail and Landscape* asked for volunteers to join a development team to produce a web site for the Ottawa Field-Naturalists' Club. Sandra Garland was one of the individuals who stepped forward, although she had little previous experience with the Internet and was already devoting many volunteer hours to the Fletcher Wildlife Garden. She was duly appointed as Web Master. In the ensuing years, Sandy has spent countless hours developing original material, transforming information submitted by the club's committees and individual members into web pages, adding graphic images, and conducting maintenance on the site to keep it both fresh and timely.

The site now has sections showcasing the activities of many of our club's committees. For example, the club's publications are highlighted, with on-line tables of contents and notes on the availability of books and special issues of our journals for purchase. Sandy has taken the time to discuss the techniques for web page production with members of the Macoun Field Club, our junior naturalists, who now have their own sub-site complete with articles, photographs and images, and notes of their upcoming activities.

Extensive information is available on the Fletcher Wildlife Garden, denoting yet another of Sandy's interests in the club, including an outstanding "virtual-tour" of the garden for web surfers who cannot visit Ottawa in person.

Although regular web surfers may recognize pleasing page design, they probably do not appreciate the underlying skills which are required to produce the look-and-feel which they experience, nor how much time and effort is required to ensure that the page content is accurate and always current. This was acknowledged in the Autumn, 2000 issue of *Nature Canada*, where Curt Schroeder, the Nature On-Line columnist, wrote:

"Naturalist groups are getting better at using the power of the Internet to communicate to their members and the public. One of the best sites I have seen belongs to the Ottawa Field-Naturalists' Club. The site... is well designed with excellent sub-section navigation... the Ottawa club has done a great job in promoting their activities on the web."

Such praise is well deserved by one very special individual. The Ottawa Field-Naturalists' Club wishes to express its own appreciation for the exemplary dedication and enthusiasm of Sandy Garland, our Web Master, by presenting her with the Member of the Year Award for 2000.

AWARDS COMMITTEE IRWIN M. BRODO (Chair),
CHRISTINE HANRAHAN, STEPHEN DARBISHIRE and
SHEILA THOMSON

News and Comment

***Froglog*: Newsletter of the Declining Amphibian Populations Task Force (47, 48)**

Number 47, October 2001, contains: DAPTF seed grants — Endangered Chinghai Salamander colonising newly created breeding habitat (Max Spaareboom, Xie Feng and Fei Liang) — Amphibian decline in Venezuela: the state of knowledge (Cesar Luis Barrio Amoros) — Froglog Shorts — Publications of Interest.

Number 48, December 2001, contains: Project Anuran (Emily Fitzherbert and Tony Gardner) — Disinfection of *Ambystoma tigrinum* virus (ATV) (Jesse Brunner and Tim Sesterhenn) — Is the canary singing? (A. Stanley Rand) — A hierarchical approach in studying the effects of an insecticide on amphibian communities (Michelle D. Boone, Christine M. Bridges, and Nathan E. Mills) — Report on the roundtable organized by DAPTF monitoring protocols working group, 15 July 2001 — Assessing the conservation status of Australian frogs (IUCN — ASH Workshop 6-9 February 2001) — Recent studies of European frogs reveal complexities of the link with UV-B (Tim Halliday, DAPTF

International Director) — Farmland tree frog conservation project (Reprinted from the International Conservation Newsletter 9(2), 2001, of the Society for Wildlife and Nature (SWAN), Taiwan) — Froglog Shorts — Publications of Interest — Instructions to Contributors.

Froglog is the bi-monthly newsletter of the Declining Amphibian Populations Task Force of The World Conservation Union (IUCN)/Species Survival Commission (SSC) and is supported by The Open University, The World Congress of Herpetology, The Smithsonian Institution, and Harvard University. The newsletter is Edited by John W. Wilkinson, Department of Biological Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail: daptf@open.ac.uk. Funding for *Froglog* is underwritten by the Detroit Zoological Institute, P. O. Box 39, Michigan 48068-0039, USA. *Froglog* can be accessed at <http://www2.open.ac.uk/biology/froglog/>

***Marine Turtle Newsletter* (94)**

The October 2001 issue, 32 pages, contains: EDITORIAL: MTN/MTM: Status Update (Brendan J. Godley and Annette C. Broderick) — ARTICLES: Post-nesting movements of the green turtle, *Chelonia mydas*, nesting in the south of Bioko Island, Equatorial Guinea, West Africa (J. Tomas, A. Formia, J. Castroviejo, and J. A. Raga) — Commensal barnacles of sea turtles in Brazil (Leandro Bugoni, Ligia Krause, Alexandre Oliveira de Almeida and Alessandra Angelica de Padua Bueno) — N NOTES: Link between green turtles foraging in Brazil and nesting in Costa Rica? (Eduardo H. S. M. Lima and Sebastian Troeng) — Notes on the trade in marine turtle products in Bangladesh (M. Zahirul Islam) — An oft told story: man's impact on green turtles in the Caribbean, circa 1720 (Michael G. Frick and Arnold Ross) — Long distance transportation of turtle eggs from Sukabumi to Bali (Indonesia)

(Ismu Sutanto Suwelo, Saddon Silalahi, and Adang Gunawan) — MEETING REPORTS: ANNOUNCEMENTS — BOOK REVIEWS — NEWS & LEGAL BRIEFS — RECENT PUBLICATIONS.

The Marine Turtle Newsletter is edited by Brendan J. Godley and Annette C. Broderick, Marine Turtle Research Group, School of Biological Sciences, University of Wales, Swansea, SA2 8PP Wales, United Kingdom; e-mail MTN@swan.ac.uk; Fax +44 1792 295447. Subscriptions to the MTN and donations towards the production of MTN and its Spanish edition NTM [Noticiero de Tortugas Marinas] should be sent to Marine Turtle Newsletter c/o Chelonian Research Foundation, 168 Goodrich Street, Lunenburg, Massachusetts 01462 USA; e-mail RhodinCRF@aol.com; fax + 1 978 582 6279. MTN web-site is: <<http://www.seaturtle.org/mtn/>>

***Point Pelee Natural History News* 1(3), 1(4)**

This newsletter for Point Pelee, Ontario, is edited by Alan Wormington (e-mail: wormington@juno.com). Editorial Assistants are M. Lea Martell and Matthew J. Smith. The web site is www.wincom.net/~fopp/Natural_History_News.htm

1(3), Fall 2001, contains: ARTICLES: Biological Invasions of a Lake Erie (Joseph H. Leach) — Noteworthy Bird Records: September to November 2001 (Alan Worthington) — "Western" Solitary Sandpiper: New to Ontario (Alan Worthington) — IN THE FIELD

1(4), Winter 2001, contains: ARTICLES: Wood Stork: New to Essex County (Alan Wormington) — Noteworthy bird records: June to August 2001 (Alan Wormington) — Dainty Sulphur: New to Essex County (Henrietta T.

O'Neill) — Point Pelee Butterfly Count: August 11, 2001 (Sarah Rupert) — Zabulon Skipper: New to Ontario and Canada (Jerry Ball, Thomas A. Hanrahan, and Paul R. Desjardins) — Clouded Skipper: New to Ontario and Canada (Henrietta O'Neill and Alan Wormington) — I — IN THE FIELD — NEWS AND ANNOUNCEMENTS — UPCOMING EVENTS AND OUTINGS.

Subscription rates are Canada: CAN \$15 (one year) or \$30 (two years); International: US \$15 (one year) or \$30 (two years). Send payment (and e-mail address, optional) to The Friends of Point Pelee, 1118 Point Pelee Drive, Leamington, Ontario N8H 3V4. Issues will be mailed in March, June, September, and December, and back issues will be available for \$15 per Volume/ \$5 per issue (postage paid).

Canadian Species at Risk November 2001

Issued by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), the list is 32 pages containing [1] About COSEWIC, (mandate, membership, definitions); — [2] Summary Tables (COSEWIC species at risk, not at risk, and data deficient; results of November 2001 COSEWIC meeting), [3] COSEWIC Lists (Explanation of symbols, Geographical occurrence and abbreviations; List 1 Species designated in the five “risk” cate-

gories, List 2. Species examined and designated in the NOT AT RISK category; List 3 Species examined and designated in the DATA DEFICIENT category) — [4] Record of Status Re-examinations — [5] List of name changes.s.
It is available from COSEWIC Secretariat, Chief, Coleen Hyslop, c/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3. See Web site: <http://www.cosewic.gc.ca>

Renew (Recovery of Nationally Endangered Wildlife) Report 11: 2000-2001 Annual Report

Contents: Report from Co-Chairs — Highlights of 2000-2001 [Of 107 Endangered and 76 Threatened species on the November 2000 COSEWIC list: 64 have recovery teams in place, 19 have approved plans, 6 more waiting approval, 25 have recovery plans or strategies in draft form, 68 are the focus of recovery efforts, 40 others are included in ecosystem recovery, 17 show stable or increasing population trends, \$26.6 million expended on recovery (salaries + expenses), employment equivalent to

about 129 salaried and 25 volunteer people working full-time, and 214 organizations have made financial contributions] — Approaches to Recovery — Species at risk web site coverage [“Species search” web site: www.speciesatrisk.gc.ca/Species/English/SearchRequest.cfm — Status of recovery planning (summaries for 69 species and 6 ecosystemstems/landscapes) — Financial contributors — Funding per species — Canadian Wildlife Directors Committee.

Amphipacifica: Journal of Aquatic Systematic Biology 3(2) 15 November 2001

CONTENTS: Donald E. McAllister (1934-2001): a tribute — The amphipod genus *Allorchestes* in the North Pacific region: systematics and distributional ecology (E. A. Hendrycks and E. L. Bousfield) — Systematics of the subterranean amphipod genus *Stygobromus* (Crangonyctidae) in western North America, with emphasis on the *hubbsi* group (Daqing Wang and John R. Holsinger).

Amphipacifica is published by Amphipacifica Research

Publications. Dr. E. L. Bousfield, Managing Editor, Ottawa; Dr. D. G. Cook, Technical Editor, Greely, Ontario. Subscriptions (4 numbers per volume) are renewable at \$50 (Can) or \$40 (US) including surface postage. Author charges are \$25 per printed page, subject to change. For further information please contact Dr. E. L. Bousfield, Managing Editor, 1710-1275 Richmond Road, Ottawa, Ontario, Canada K2B 8E3; e-mail: elbousf@magma.ca

Conserving Borderline Species: A Partnership between the United States and Canada

The Canadian Wildlife Service, Environment Canada, has published a 28-page booklet (including covers) on the “Framework for Cooperation between the U.S. Department of the Interior and Environment Canada in the Protection and Recovery of Wild Species at Risk” that was signed 7 April 1997 “to facilitate cooperation in identifying and recovering shared species at risk”.

“The goal of the Framework is to prevent populations of wild species shared by the United States and Canada from becoming extinct as a consequence of human activity, through the conservation of wildlife populations and ecosystems on which they depend.” The booklet text covers: Introduction (United States Fish and Wildlife Service and the Canadian Wildlife Service are responsible for imple-

menting the Framework; since these have varying jurisdictions, the Framework does not consider issues involving marine mammals, fish, or sea turtles); Species accounts (Black-footed Ferret, Swift Fox, Woodland Caribou, Grizzly Bear, Whooping Crane, Piping Plover, Marbled Murrelet, Lake Erie Water Snake, Karner Blue Butterfly, Western Prairie Fringed Orchid); Table of Shared Species; What You Can Do (Report, Observe, Cooperate, Join, Inform, Do not disrupt, Ensure, Learn, Respect, Protect); For more information (in Canada contact Canadian Wildlife Service at 1-800-668-6767 or www.speciesatrisk.gc.ca; in United States contact U.S. Fish and Wildlife Service at 1-800-344-WILD or visit [<http://endangered.fws.gov>]); Text of Framework.

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